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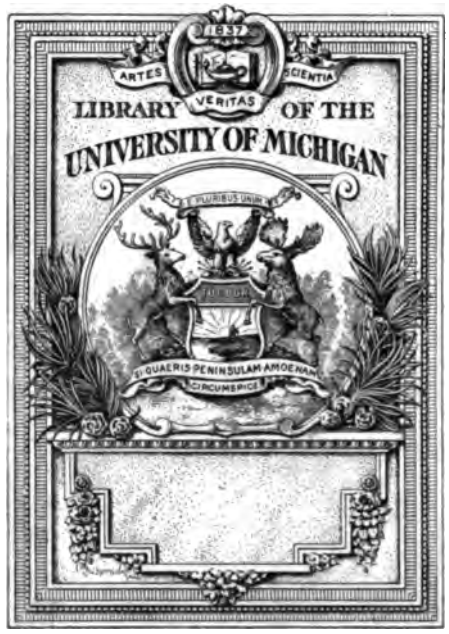
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THE GIFT OF

60th Congress 2d Sess. H. Doc. 7. 96. 5365

ANNUAL REPORT
OF THE BOARD OF REGENTS OF

THE SMITHSONIAN INSTITUTION

SHOWING THE OPERATIONS, EXPENDITURES
AND CONDITION OF THE INSTITUTION
FOR THE YEAR ENDING JUNE 30

1907

WASHINGTON
GOVERNMENT PRINTING OFFICE
1908

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

ACCOMPANYING

The Annual Report of the Board of Regents of the Institution for the year ending June 30, 1907.

SMITHSONIAN INSTITUTION,
Washington, April 24, 1908.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the Annual Report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1907.

I have the honor to be, very respectfully, your obedient servant,

CHAS. D. WALCOTT,
Secretary.

204485

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1907.

SUBJECTS.

1. Proceedings of the Board of Regents for the sessions of December 4, 1906, and January 23 and March 6, 1907.

2. Report of the executive committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, and receipts and expenditures for the year ending June 30, 1907.

3. Annual report of the Secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1907, with statistics of exchanges, etc.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1907.

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MEMBERS EX OFFICIO OF THE "ESTABLISHMENT."

June 30, 1907.

THEODORE ROOSEVELT, President of the United States.
CHARLES W. FAIRBANKS, Vice-President of the United States.
MELVILLE W. FULLER, Chief Justice of the United States.
ELIHU ROOT, Secretary of State.
GEORGE B. CORTELYOU, Secretary of the Treasury.
WILLIAM H. TAFT, Secretary of War.
CHARLES J. BONAPARTE, Attorney-General.
GEORGE VON L. MEYER, Postmaster-General.
VICTOR H. METCALF, Secretary of the Navy.
JAMES R. GARFIELD, Secretary of the Interior.
JAMES WILSON, Secretary of Agriculture.
OSCAR S. STRAUS, Secretary of Commerce and Labor.

REGENTS OF THE SMITHSONIAN INSTITUTION.

By the organizing act approved August 10, 1846 (Revised Statutes, Title LXXIII, section 5580), "The business of the Institution shall be conducted at the city of Washington by a Board of Regents, named the Regents of the Smithsonian Institution, to be composed of the Vice-President, the Chief Justice of the United States, three members of the Senate, and three members of the House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the city of Washington, and the other four shall be inhabitants of some State, but no two of the same State."

REGENTS FOR THE YEAR ENDING JUNE 30, 1907.

	Term expires.
The Chief Justice of the United States:	
MELVILLE W. FULLER, elected Chancellor and President of the Board January 9, 1889.	
The Vice-President of the United States:	
CHARLES W. FAIRBANKS, ex officio March 4, 1905	Mar. 3, 1909

United States Senators:

SHELBY M. CULLOM (appointed March 24, 1885; March 28, 1889; December 18, 1895; March 7, 1901, and March 4, 1907) ---------- Mar. 3, 1913

HENRY CABOT LODGE (appointed December 7, 1905) ---------- Mar. 3, 1911

AUGUSTUS O. BACON (appointed December 7, 1905, and March 4, 1907) ---------- Mar. 3, 1913

Members of the House of Representatives:

JOHN DALZELL (appointed June 12, 1906) ---------- Dec. 25, 1907

JAMES R. MANN (appointed December 3, 1906) ---------- Dec. 25, 1907

WILLIAM M. HOWARD (appointed December 13, 1905) ---------- Dec. 25, 1907

Citizens of a State:

JAMES B. ANGELL, of Michigan (appointed January 19, 1887; January 9, 1893; January 24, 1899, and January 23, 1905) ---------- Jan. 23, 1911

ANDREW D. WHITE, of New York (appointed February 15, 1888; March 19, 1894; June 2, 1900, and April 23, 1906) ---------- Apr. 23, 1912

RICHARD OLNEY, of Massachusetts (appointed January 24, 1900, and February 23, 1906) ---------- Feb. 23, 1912

GEORGE GRAY, of Delaware (appointed January 14, 1901, and January 21, 1907) ---------- Jan. 21, 1913

Citizens of Washington City:

JOHN R. HENDERSON (appointed January 26, 1892; January 24, 1898, and January 27, 1904) ---------- Jan. 27, 1910

ALEXANDER GRAHAM BELL (appointed January 24, 1898, and January 27, 1904) ---------- Jan. 27, 1910

Executive Committee of the Board of Regents.

JOHN R. HENDERSON, *Chairman.*

ALEXANDER GRAHAM BELL. JOHN DALZELL.

OFFICERS OF THE INSTITUTION.

CHARLES D. WALCOTT, *Secretary.*

RICHARD RATHBUN, *Assistant Secretary, in Charge of U. S. National Museum.*

CYRUS ADLER, *Assistant Secretary, in Charge of Library and Exchanges.*

PROCEEDINGS OF THE BOARD OF REGENTS FOR THE YEAR ENDING JUNE 30, 1907.

At a meeting held March 12, 1903, the Board of Regents adopted the following resolution:

Resolved, That, in addition to the prescribed meeting held on the fourth Wednesday in January, regular meetings of the Board shall be held on the Tuesday after the first Monday in December and on the 6th day of March, unless that date falls on Sunday, when the following Monday shall be substituted.

In accordance with this resolution, the Board met at 10 o'clock a. m. on December 4, 1906, and on January 23 and March 6, 1907.

REGULAR MEETING OF DECEMBER 4, 1906.

Present: Mr. Chief Justice Fuller (Chancellor) in the chair; the Vice-President, the Hon. Charles W. Fairbanks, Senator S. M. Cullom, Senator Henry Cabot Lodge, Senator A. O. Bacon, Representative John Dalzell, Representative James R. Mann, Representative W. M. Howard, Dr. Andrew D. White, the Hon. John B. Henderson, Dr. A. Graham Bell, the Hon. Richard Olney, the Hon. George Gray, and the Acting Secretary, Mr. Richard Rathbun.

DEATH OF REPRESENTATIVE ROBERT ADAMS, JR.

The Chancellor announced the death on June 1, 1906, at Washington, D. C., of Representative Robert Adams, jr., a Regent of the Institution, and the following resolution, offered by Doctor Bell, was adopted by a rising vote:

The Board of Regents of the Smithsonian Institution have learned with profound regret of the death on June 1, 1906, of the Hon. Robert Adams, jr., for ten years a member of the Board, and here place upon record an expression of their deep sorrow at his loss, and of appreciation of his earnest interest in the welfare of the Institution and of his labors on its behalf both at the meetings of the Board and in the House of Representatives.

Resolved, That a copy of this minute be spead upon the records of the Board and communicated to the family of Mr. Adams.

DEATH OF REPRESENTATIVE R. R. HITT.

The Chancellor announced the death at Narragansett Pier, R. I., on September 20, 1906, of Representative Robert R. Hitt, a Regent of the Institution, and the following resolution, submitted by Senator Cullom, was adopted by a rising vote:

The Board of Regents of the Smithsonian Institution have learned with profound sorrow of the passing away on September 20, 1906, of the Hon. Robert Roberts Hitt, for thirteen years a Regent of this Institution, and since 1901 a member of the executive committee; and they here place upon record an expression of their sense of loss in the demise of their distinguished colleague.

Mr. Hitt for a period of more than forty years served his country in various diplomatic offices, in the Department of State and in the halls of the National Legislature, where, besides furthering all good measures, he was particularly distinguished because of his wise action as chairman of the Committee on Foreign Affairs, using all his efforts to promote the welfare of his country and the peace of the world. His broadly cultivated mind was especially adapted to labors on behalf of this Institution, and at all times as a Representative, a member of the Board, and a member of the executive committee, he served its interests with ability, fidelity, and conscientiousness.

To the members of the Board he was a dear friend and a wise counsellor, and his absence from our midst is a source of grief and a serious loss.

The Board tender to Mrs. Hitt and to the family an expression of their sincere condolence, with the assurance that the memory of her distinguished husband will ever be cherished by his colleagues.

Resolved, That a copy of this minute be spread upon the records of the Board and communicated to Mrs. Hitt.

APPOINTMENT OF REGENTS.

The Chancellor announced the reappointment of Dr. Andrew D. White as a Regent by joint resolution of Congress approved April 23, 1906, and of the following appointments by the Speaker on the part of the House of Representatives: On June 12, 1906, the Hon. John Dalzell in place of Representative Robert Adams, jr., deceased; and on December 3, 1906, the Hon. James R. Mann in place of Representative Robert R. Hitt, deceased.

ELECTION OF SECRETARY.

The Board went into executive session, at which Prof. Henry Fairfield Osborn, of New York, was elected Secretary of the Institution. The Chancellor was requested to notify Professor Osborn of this action.

ANNUAL MEETING OF JANUARY 23, 1907.

Present: Mr. Chief Justice Fuller (Chancellor), in the chair; the Vice-President, the Hon. Charles W. Fairbanks, Senator S. M. Cullom, Senator Henry Cabot Lodge, Senator A. O. Bacon, Representative John Dalzell, Representative James R. Mann, Representative

William M. Howard, Dr. James B. Angell, the Hon. John B. Henderson, Dr. Alexander Graham Bell, the Hon. George Gray, and the Acting Secretary, Mr Richard Rathbun.

The Chancellor stated that he had informed Prof. Henry F. Osborn of his unanimous election at the December meeting as Secretary of the Institution, and had received a reply to the effect that though fully appreciating the honor tendered, he had found himself unable to accept for reasons set forth at large.

REAPPOINTMENT OF REGENT.

The Chancellor announced the reappointment of Judge George Gray as a Regent for six years, by joint resolution of Congress approved by the President on January 21, 1907.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

Mr. Henderson, chairman of the executive committee, submitted the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1908, be appropriated for the service of the Institution, to be expended by the Secretary with the advice of the executive committee, with full discretion on the part of the Secretary as to items.

ANNUAL REPORT OF THE ACTING SECRETARY.

The Acting Secretary submitted his report upon the operations of the Institution for the year ending June 30, 1906, which was accepted.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Mr. Henderson, chairman, presented the report of the executive committee for the year ending June 30, 1906, and explained briefly the method of auditing the accounts of the Institution and of the Government branches under its charge. On motion the report was adopted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

Mr. Henderson, chairman, presented the following report of the permanent committee:

Hodgkins estate.—In addition to the fund of $200,000 donated to the Institution by the late Thomas George Hodgkins in 1891, the residual estate, embracing $8,000 in cash, certain West Shore Railroad bonds of the value of approximately $42,000, and the sum of $8,772.38 invested in United States 4 per cent bonds of 1907, together with two small properties in Elizabeth, N. J., later sold by authority

of the Board of Regents for $600 and $1,000 respectively, was bequeathed to the Institution under the will of Mr. Hodgkins. The West Shore Railroad bonds and the $8,000 in cash were transmitted into the custody of the Institution upon the death of the testator, but the United States 4 per cent bonds were left by consent of counsel to be held by the New York Life and Trust Company until a decision could be obtained in the case of Smith *v.* O'Donoghue, in which the liability of the estate of Mr. Hodgkins on a warranty of title by him in the transfer of certain real property in New York City in 1872 was in question. The case was decided by the supreme court of New York in the Institution's favor, which decision was recently confirmed by the court of appeals of that State. The bonds, of a nominal value of $7,850, were received and duly registered in the name of the Institution on May 28, 1906. The committee is prepared to recommend that the bonds be sold and the proceeds deposited in the Treasury.

Andrews estate.—An appeal has been taken from the decision sustaining the bequest of Mr. Andrews for the establishment of the Andrews Institute for Girls, now organized at Willoughby, Ohio. In case of the invalidity of this provision, the sum involved would accrue to the Smithsonian Institution. The case was argued on behalf of the Andrews Institute, the heirs, and the Smithsonian Institution before the appellate division of the supreme court of New York City, in May, 1906, and a decision is now being awaited. Whatever conclusion may be reached by the court it is quite probable (since the disposition of more than a million and a half dollars is involved) that the case will be taken to the court of appeals at Albany.

Avery estate.—With the exception of the premises conveyed by the Institution to the niece of the late Robert Stanton Avery, in recognition of her services during his illness, the Institution is still in possession of the real estate bequeathed by Mr. Avery, consisting of four properties on Capitol Hill, having a present estimated value of about $35,500. Owing to the erection of office buildings for the Senate and House of Representatives and the location of the new Union Station in the neighborhood of these properties, it is understood that their market value has considerably increased. Three of the four lots contain small buildings from which a net annual revenue of about $300 is derived. In addition to the real estate, certain stocks, bonds, and cash, estimated at the time of the death of Mr. Avery at $2,915.87, are being held by the National Safe Deposit, Savings and Trust Company of this city, the income to be paid to the niece of the testator during her lifetime, and the principal to become the property of the Institution upon her demise.

Sprague and Reid bequests.—Under the terms of the Sprague and Reid bequests, the residual legacies will not accrue to the Smithsonian Institution until the death of certain enumerated legatees, and it is

probable that the Institution will not derive any actual income from these estates for some years to come.

The chairman then submitted the following resolution, which was adopted:

Resolved, That the Secretary be, and he is hereby, authorized, in his discretion, to sell before maturity, or to present for redemption and collect when due, the United States 4 per cent bonds, of the nominal value of $7,850, derived from the estate of the late Thomas G. Hodgkins; and he is empowered and directed to deposit the proceeds therefrom in the Treasury of the United States, to be held under the terms of section 5591 of the Revised Statutes, as an addition to and a part of the permanent fund of the Institution.

THE FREER ART COLLECTION.

With reference to the action of the Board, at their annual meeting of January 24, 1906, in accepting the tender of Mr. Charles L. Freer to make present conveyance to the Institution of the title to his art collection, and to bequeath to the Institution the sum of $500,000, for the construction of a building in which to house it, under the terms of his offer dated December 15, 1905, the Acting Secretary stated that on May 5, 1906, a document embracing these provisions was formally executed by Mr. Freer and delivered into the custody of the Institution.

ELECTION TO THE EXECUTIVE COMMITTEE.

The vacancy on the executive committee caused by the death of Representative Robert R. Hitt was filled by the election of Representative John Dalzell.

MEDALS AND TOKENS OF THE LATE SECRETARY LANGLEY.

The following resolutions having reference to the donation by the heirs of Mr. Langley, announced at the meeting of May 16, 1906, were adopted:

Resolved, That the thanks of the Board of Regents of the Smithsonian Institution be tendered to Prof. John W. Langley, Mrs. Annie W. Ciocca, Mrs. Julia H. Goodrich, and Mr. Pierpont Langley Stackpole for the gift of the medals, scientific tokens, and early scientific apparatus of Samuel Pierpont Langley, Secretary of the Institution from 1887 to 1906.

Resolved, That the Board expresses its deep appreciation at securing for the Institution possession of this memorial of its late distinguished Secretary.

DONATION OF LEPIDOPTERA BY MR. WILLIAM SCHAUS.

The Acting Secretary announced the presentation to the National Museum, during the previous year, by Mr. William Schaus, of New York, of his exceptionally valuable collection of Lepidoptera from tropical North and South America, numbering over 75,000 specimens

and containing many types and rare species; whereupon the following resolution was adopted:

Resolved, That the thanks of the Board of Regents be tendered to Mr. William Schaus for his generous gift to the National Museum of his extensive and valuable collection of Lepidoptera, which is gratefully accepted.

PORTRAIT OF DR. ELLIOTT COUES.

The following letter from Ellen S. Mussey, addressed to the Chancellor, was read:

JANUARY 8, 1907.

Mr. CHANCELLOR: I have the honor to inform you that Mrs. Mary Emily Bates Coues, widow of Dr. Elliott Coues, died in February last, and by will left to the Smithsonian Institution a portrait of the late Dr. Elliott Coues, and "also a paper received by him, inviting him to visit London as the guest of scientific men, signed by Darwin, Huxley, etc., the letter to be framed and hung under Doctor Coues's portrait."

This will has been duly admitted to probate, and the American Security and Trust Company and myself, named as executors therein, have qualified in such capacity.

We understand that the portrait is now in the possession of the Smithsonian Institution; the other paper referred to is in our possession, and we should be pleased to have it properly framed so that each side of the paper can be seen, to be hung as stipulated in the will, provided the Regents will accept the gift as named.

Awaiting the favor of your reply, I am,

Very respectfully,

(Signed) ELLEN S. MUSSEY,
Co. Ex. Will M. E. B. Coues.

After an examination of the portrait, which had been deposited at the Institution for some years, the following resolution was adopted:

Resolved, That the portrait of Elliott Coues, bequeathed by Mary Emily Bates Coues, be accepted in accordance with the terms of the will as expressed in the letter of Ellen S. Mussey to the Chancellor, under date of January 8, 1907.

STATEMENT BY THE ACTING SECRETARY.

The Acting Secretary reported that the actual erection of the new building for the National Museum, except interior finish, had reached practically one-half the full height, although the south pavilion, which included the entrance rotunda, was still at the basement stage of construction. In addition, there was on the ground around the building all of the dressed granite for the third or attic story and all the materials, including special white face bricks and cut granite for the entire completion of the walls of the two courts. There were also on hand large quantities of the plainer materials. All of the

dressed granite required for the exterior walls of the building, consisting only of the second story and the exterior walls of the main pavilion, was under contract and its manufacture under way at the quarries. All of the remaining steelwork required for the building was also under contract, and all except that for the roof was ready for erection. Should the balance of the granite be furnished in accordance with the contracts, it was fair to expect that the entire building would be completed and ready for occupancy by January 1, 1909.

The Acting Secretary announced the final liquidation, since the last meeting of the Board, of the indebtedness of the Institution to the central London bureau of the International Catalogue of Scientific Literature, resulting from the defalcation of W. W. Kair.

He also stated that the initial steps taken toward the building up of a National Gallery of Art had continued to attract widespread attention and to receive favorable comment. The lecture hall in the Museum building had been temporarily adapted to this purpose, and its walls were already fairly well covered with pictures, including, besides those owned by the Government, a number of choice paintings obtained by loan. Art objects other than paintings, selected from the collections of the Museum, occupied the floor space, and it was expected, as soon as the installation was perfected, that the hall would present a very creditable appearance.

Reference was made to the increasing demand for the Annual Report of the Institution and the effort to prevent the duplication resulting from sending the Smithsonian edition to public depositories which were also supplied by the Superintendent of Documents. Of the replies received to the present time, some 90 per cent were of the nature of earnest appeals that the Institution continue to send its edition, accompanied by many gratifying remarks as to the esteem in which the report is held, and the great demand for it among readers.

ELECTION OF A SECRETARY.

The Board then went into executive session, and Dr. Charles Doolittle Walcott, of Washington, was unanimously elected Secretary of the Institution, to fill the vacancy caused by the death of Dr. S. P. Langley.

REGULAR MEETING OF MARCH 6, 1907.

Present: Mr. Chief Justice Fuller (Chancellor) in the chair; Senator S. M. Cullom, Senator Henry Cabot Lodge, Senator A. O. Bacon, the Hon. John B. Henderson, Dr. A. Graham Bell, and the Secretary, Mr. Charles D. Walcott.

REAPPOINTMENT OF REGENTS.

The Chancellor announced that the Vice-President had reappointed Senators Cullom and Bacon as Regents, dating from March 4.

ANDREWS WILL DECISION.

Mr. Henderson, chairman of the permanent committee, read a letter from Mr. F. W. Hackett, counsel for the Institution, giving a statement of the adverse decision in regard to the Institution's suit in the Andrews will case by the appellate division of the supreme court of New York.

CLAIM OF BELL & CO.

Senator Bacon, acting with the executive committee on this claim, submitted a letter and report on this subject, and after discussion the following resolution was adopted:

Resolved, That the Secretary be authorized to include in the estimates for the fiscal year 1908–9 for the Bureau of American Ethnology an item to cover the claim of Bell & Co., setting forth the facts.

ACKNOWLEDGMENTS.

The Secretary read a letter from Mrs. R. R. Hitt, acknowledging the resolutions adopted by the Board on the death of her husband; also a letter from Prof. John W. Langley, acknowledging the action of the Board in connection with the gift of the medals and scientific tokens and apparatus of his brother, the late Secretary S. P. Langley.

SALE OF BONDS.

The Secretary said that, in accordance with the resolution of the Board at the meeting of January 23, 1907, the Government bonds to the par value of $7,850, being the residuary Hodgkins legacy, were sold on February 5, 1907, to Lewis Johnson & Co., bankers, for $7,918.69, and this amount deposited to the credit of the permanent Smithsonian fund in the United States Treasury. The bonds matured July 1, 1907; selling price, 100⅞.

GIFT OF PAINTING BY MR. JOHN B. HENDERSON.

The Secretary announced the gift to the Institution by Mr. Henderson of a large painting of the Yellowstone Canyon.

Senator Cullom, after remarks by Regents, submitted the following resolution, which was adopted:

Resolved, That the Board of Regents of the Smithsonian Institution hereby tender their appreciative thanks to the Hon. John B. Henderson, one of their number, for his public-spirited generosity in presenting a valuable painting of the Yellowstone Canyon to the Institution for its National Gallery of Art.

AUTHORITY FOR THE SECRETARY TO INDORSE CHECKS, ETC.

The Secretary said that the Comptroller of the Treasury had informally called the attention of the accountant of the Institution to the fact that there was no specific authority of the Board of Regents on file in the Treasury Department empowering the Secretary of the Smithsonian Institution to receipt for moneys and to indorse warrants and checks in the name of the Institution for moneys due. He would suggest, therefore, the following form of resolution, which if adopted, would be acceptable to the Comptroller:

Resolved, That the Secretary of the Smithsonian Institution be, and he is hereby, authorized to receive and give receipt for all moneys due and payable to this Institution from any source whatsoever, and to indorse warrants and checks in its name and on its behalf.

The Secretary stated that for the past sixty years this had been done, but the present Comptroller in looking over the business methods of his office noticed the lack of such specific authority, and asked that it be furnished.

On motion, the resolution was adopted.

ACCOUNTS TO BE AUDITED SEMIANNUALLY.

The Secretary said that at the meeting of the Board of Regents held February 22, 1867, the following resolution was adopted:

Resolved, That the Executive Committee make a quarterly examination of the books and accounts of the Institution, and, as usual, an annual report to the Board of Regents.

This had been followed somewhat irregularly; at times there would be an audit four times a year, and again twice a year. At present there was a trained auditor employed to examine the accounts, and his report for the last six months of the year 1906 had been received. It was the practice in the Carnegie Institution to have but one audit a year, and in most of the large financial organizations two had been found sufficient.

Mr. Henderson said that two audits a year would certainly be enough, and submitted the following resolution, which was adopted:

Resolved. That hereafter the accounts of the Institution shall be audited semiannually under the direction of the Executive Committee.

FEE FOR ARCHITECTS.

The Chancellor read the following letter and inclosure from Mr. Bernard R. Green:

BUILDING FOR THE NATIONAL MUSEUM,
BERNARD R. GREEN, SUPERINTENDENT OF CONSTRUCTION,
LIBRARY OF CONGRESS,
Washington, D. C., March 5, 1907.

SIR: By the terms of the contract entered into May 18, 1903, with Hornblower & Marshall as architects for the new National Museum building, their compensation was fixed at 3½ per cent on the "cost of the construction of the

said building after excluding the architects' fee and the contingent cost of the services and office expenses of the party of the first part," and that, further, they should receive for such personal supervision of the construction as might be called for from time to time additional compensation within a total limit of 1½ per cent on the cost of the construction as above described.

An arrangement with the architects for compensation for their personal supervision under the second provision of the contract should no longer be delayed. They have already rendered more or less of such service in the progress of the work up to the present time. Hitherto payments have been made from time to time on account of the 3½ per cent portion of their compensation amounting to $95,000, but they have received no compensation for personal supervision.

The work that the architects have already done has been unusually expensive to them, because of the numerous restudies of design and arrangement of the building to meet the conditions of location, the limitation of its cost, and the requirements of its internal arrangement, the result of which is to be a building of far superior design and adaptation for its purposes, all within the limit of cost fixed by law, than was provided for in the original design upon which the law was based. The architects have spared no expense of time, labor, travel, and scale modeling of important parts of the building in order to arrive at the result mentioned. There yet remains much work for them to do in the details for the completion, especially the interior of the building, not only in study and design, but in personal supervision of the construction.

Under the present conditions, therefore, I have the honor to recommend that authority be given me to employ the personal supervision of the architects, under the provision of the contract therefor, until the entire completion of the building, at a rate of compensation equal to 1½ per cent on the cost of the construction of the building as defined in the contract.

I inclose herewith for your convenience a copy of the contract and page xix of the Proceedings of the Board of Regents at its meeting on January 28, 1903, containing the original law for the construction of the building and the resolution of the Regents providing for the direction of the work by the Regents through me.

Yours very respectfully, (Signed) BERNARD R. GREEN,
Superintendent of Construction.

Dr. CHAS. D. WALCOTT,
Secretary, Smithsonian Institution, Washington, D. C.

Articles of agreement entered into this eighteenth day of May, nineteen hundred and three (1903), between Bernard R. Green, superintendent of the building and grounds, Library of Congress, of the first part, acting under the direction of the Regents of the Smithsonian Institution, for and in behalf of the United States of America, and Joseph C. Hornblower and James R. Marshall, partners doing business as architects under the firm name of Hornblower & Marshall, of Washington, in the District of Columbia, of the second part:

This agreement witnesseth, that whereas by act of Congress approved March 3, 1903, the said Regents were authorized to commence the erection of a suitable building for the use of the National Museum on the north side of the Mall between Ninth and Twelfth streets northwest, said building to cost not exceeding three million five hundred thousand dollars, the construction of said building to be in charge of the said Bernard R. Green, who shall make all contracts for the

and

Whereas it is indispensable to the proper design and construction of so important a permanent public building that an architect or firm of architects of the requisite talent, skill, and experience should be employed for that purpose;

The said Bernard R. Green (with the concurrence and consent, and under the direction of the said Regents) and the said Hornblower & Marshall all have mutually agreed, and by these presents do mutually covenant and agree, to and with each other, as follows, to wit:

That, for the consideration hereinafter mentioned, the said party of the second part shall, under the direction and to the entire satisfaction of the said party of the first part acting as aforesaid, make the design and prepare and furnish all the necessary plans, the working and other needful drawings, details, specifications, and estimates required for the construction complete of the said building for the National Museum, including all necessary modifications that may be made therein during the progress of the work.

And the said party of the second part further covenants and agrees to furnish to the party of the first part, without cost to the United States, one set of tracings of all working drawings, including details, and two copies of specifications, all of which shall remain in the custody of the party of the first part and be and remain the property of the United States.

And the party of the second part further covenants and agrees to make, when required so to do by the party of the first part, without expense to the United States, such revisions and alterations in the working drawings and specifications of said building as may be necessary to insure its proper construction and completion within the limit of cost fixed by the party of the first part, and to furnish all drawings, details, specifications, estimates, etc., in such sequence and at such times as, in the judgment of the party of the first part, may be necessary to insure the continuous and prompt prosecution of the work of construction.

And the party of the first part covenants and agrees to pay to the party of the second part, or to their heirs, executors, or administrators a fee computed at the rate of three and one-half (3½ %) per centum upon the cost of the construction of the said building, after excluding the architects' fee and the contingent cost of the services and office expenses of the party of the first part, all to be determined by the party of the first part, in the following manner, to wit: The sum of thirty thousand dollars when the preliminary drawings of the said building are completed and approved by the party of the first part less the sum of four thousand nine hundred dollars heretofore received from the United States for the tentative sketch plans made and submitted according to the act of Congress approved June 28, 1902, and the remainder of said fee shall be paid by the party of the first part in such amounts and at such times as the progress of the general drawings, details, and specifications shall warrant in the judgment of the said party of the first part.

And it is further covenanted and agreed by and between the parties hereto that the party of the second part shall furnish such personal supervision of the construction as may hereafter be called for by the party of the first part from time to time and at such rate of compensation as may be agreed upon between the parties hereto. But the entire compensation to be allowed and paid to the party of the second part under this contract shall not exceed in the aggregate an amount equal to five per centum on the cost of the construction of the building to be estimated as hereinbefore provided, nor shall it exceed in the aggregate such amount as may be fixed by the Fifty-eighth Congress for the full services of architects in the construction of Government buildings of similar character and cost: *Provided*, That no action of the Fifty-eighth Congress or any subsequent

Congress, limiting the fees of architects generally, shall of itself be construed to reduce the total compensation of the party of the second part to a sum less than five per centum on such cost of construction, it being herein understood that the fees of the architect as herein provided for shall be limited to three and one-half per cent on such cost of construction, together with such additional compensation as may be fixed and agreed to be paid from time to time by the party of the first part acting as aforesaid, which additional compensation shall not, in any event, exceed a sum equal to one and one-half per cent on such total cost of construction.

And it is herein further provided that no payment shall become due before July first, nineteen hundred and three (1903).

And it is further covenanted and agreed by and between the parties hereto that the payments herein stipulated to be made by the party of the first part shall be in full compensation and payment of all charges for the full services of the party of the second part and for all designs, plans, details, and specifications made, ordered, or prepared for the National Museum by or under the direction of the said party of the second part.

And it is further covenanted and agreed by and between the parties hereto that should the said party of the second part through any unavoidable cause become unable to complete the foregoing contract, or if the conduct of the said party of the second part is such that the interests of the United States are thereby likely to be placed in jeopardy, or if the said party of the second part violates any of the conditions or stipulations of this contract, the said party of the first part shall have the right to revoke this contract or any part thereof, and to cause the same to be otherwise completed: *Provided*, In such case, however, that the party of the second part shall receive equitable compensation for all services already properly performed under this contract up to the date of its revocation, such compensation to be fixed by the said party of the first part.

No Member or Delegate to Congress, or other person whose name is not at this time disclosed, shall be admitted to any share in this contract or to any benefit to arise therefrom; and it is further covenanted and agreed that this contract shall not be assigned.

In witness whereof the parties hereto have hereunto placed their hands and seals the day and date hereinbefore written.

BERNARD R. GREEN,
Superintendent of the Building and Grounds, Library of Congress.
HORNBLOWER & MARSHALL.

Witnesses:
JOHN Q. SHEEHY.
GEO. N. FRENCH.
(Executed in triplicate.)

The Chancellor also read the following clause from the sundry civil act approved March 3, 1903, providing for the new building for the National Museum:

BUILDING FOR NATIONAL MUSEUM: To enable the Regents of the Smithsonian Institution to commence the erection of a suitable fireproof building with granite fronts, for the use of the National Museum, to be erected on the north side of the Mall, between Ninth and Twelfth streets northwest, substantially in accordance with the Plan A, prepared and submitted to Congress by the Secretary of the Smithsonian Institution under the provisions of the act approved June twenty-eighth, nineteen hundred and two, two hundred and fifty thousand dollars. Said building, complete, including heating and ventilating apparatus and elevators, shall cost not to exceed three million five hundred thou-

sand dollars, and a contract or contracts for its completion is hereby authorized to be entered into, subject to appropriations to be made by Congress. The construction shall be in charge of Bernard R. Green, superintendent of buildings and grounds, Library of Congress, who shall make the contracts herein authorized and disburse all appropriations made for the work, and shall receive as full compensation for his services hereunder the sum of two thousand dollars annually in addition to his present salary, to be paid out of said appropriations.

He also read the following resolution adopted by the Board on January 23, 1903, providing that the Secretary be authorized to represent it in carrying out the provisions of this act:

Resolved, That the Secretary, with the advice and consent of the Chancellor and the chairman of the executive committee, be authorized to represent the Board of Regents so far as may be necessary in consultation with Bernard R. Green, to whom the construction and contracts for the new Museum building are committed by Congress in the act making an appropriation for that purpose.

After considerable discussion on the question of the architect's fee and the contract, in which all present took part, Senator Lodge submitted the following resolution, which was adopted:

Resolved, That Mr. Bernard R. Green be authorized to pay Hornblower & Marshall the fee of one and one-half per cent recommended by him, in addition to the fee of three and one-half per cent, whenever in his judgment it has, from time to time, been earned under the terms of the contract.

PROVISION FOR EMERGENCY SUPERINTENDENT OF CONSTRUCTION.

The Secretary said that the original act authorizing the new building for the National Museum provided that the construction should be in charge of Bernard R. Green, who should make the contracts authorized and disburse all appropriations made for the work. Realizing the inconvenience that would arise in case of Mr. Green becoming incapacitated, he had requested that provision be made empowering the Board of Regents, in case of this emergency, to take charge of the work of construction and to disburse appropriations made for the same; and he had to report that this provision had been included in the sundry civil act approved March 4, 1907, as follows:

BUILDING FOR NATIONAL MUSEUM: For completing the construction of the building for the National Museum, and for each and every purpose connected with the same, one million two hundred and fifty thousand dollars: *Provided*, That if the superintendent of buildings and grounds, Library of Congress, now in charge of the construction of the new Museum building and the disbursing of all appropriations made for the work, be at any time incapacitated to continue in such charge, the Board of Regents of the Smithsonian Institution is hereby empowered to take charge of the construction and to disburse appropriations made for the same.

Mr. Henderson suggested that if Mr. Green should become incapacitated between now and the next meeting in December, it would be difficult to get suitable action by the Board, and he suggested

that an arrangement should be made now to provide for such a contingency.

The following resolution was then adopted:

Resolved, That if the superintendent of construction of the new building for the National Museum, whose services are provided for in the sundry civil act approved March 3, 1903, shall become incapacitated for the performance of his duties between this date and December 3, 1907, the date of the next meeting of the Board of Regents, the Secretary of the Institution is hereby authorized and directed to personally take charge of the work of construction on behalf of the Board and to disburse appropriations made for the same, or appoint some suitable person or persons to take charge of said construction and disburse such appropriations.

SECRETARY'S STATEMENT.

The Secretary said: "I wish first to thank you for the honor you have done me in electing me Secretary of the Smithsonian Institution, and desire to say that I shall do all in my power to uphold the interests of the Institution and its branches."

(*a*) GOVERNMENTAL APPROPRIATIONS FOR 1907–8.

The Secretary then submitted the following statement with regard to increases in the appropriations for the fiscal year 1907–8:

INCREASES.

International Exchanges, $28,800 to $32,000	$3,200
Astrophysical Observatory, $14,000 to $15,000 ($2,000 of this appropriation is limited to printing one volume of the Annals)	1,000
National Museum; Preservation of Collections, $180,000 to $190,000 (for increasing pay of laborers, and increasing size of watch force)	10,000
National Zoological Park; new (for reconstructing roads)	15,000
American Historical Association, $5,000 to $7,000 (printing reports)	2,000
Total	31,200

DECREASES.

National Museum: Printing, $34,000 to $33,000	1,000
Total increase	30,200

NEW MUSEUM BUILDING.

For continuing the construction of the new building for the Museum, there was appropriated $1,250,000, being the balance on the total limitation of $3,500,000.

(*b*) BUSINESS OF THE INSTITUTION.

The Secretary stated that he had found the business of the Institution in admirable condition, that the organization of the various branches was satisfactory, and that no immediate changes would be made.

In view of the recent examination by a commission appointed by the President into the business methods of all the Government Departments, exclusive of those under the charge of the Smithsonian Institution, the Secretary thought it would be wise to appoint a committee on business methods for the purpose of examining into all the business methods of the Institution and its several branches with a view of suggesting, if found desirable, improvements in the business methods of the Institution and its various branches, and in the transaction of business between them and the Institution.

(*c*) RESEARCH WORK OF THE INSTITUTION.

The Secretary stated that of the parent fund there would be available up to July 1, 1907, somewhat over $15,000 for the uses of the Institution over and above fixed charges. For the coming fiscal year 1907–8, after providing for the regular charges, there was a prospect of about $22,000, which would be all that was available for printing and research. This was a very small fund, and it would be desirable to have more money for research and publication in the future.

(*d*) RESEARCH WORK OF THE SECRETARY.

Attention was called to the desirability of the Secretary of the Institution keeping in touch with the spirit of research work by carrying on some original investigations. Professor Henry before coming to the Institution had developed many matters of great importance in connection with electricity, and while Secretary took up the subject of meteorology and also greatly aided the Government in the establishment of the system of light-houses under the Light-House Board. Secretary Baird was a student of natural history in general, and later devoted himself to fishes. The development of the food fishes, not only of the United States but of the world, received a great impetus by the organization of the National Fish Commission as the result of his studies. Secretary Langley invented the bolometer, and used it with great success in connection with his investigations in the Astrophysical Observatory and his study of solar physics.

The Secretary added that his own research work had been in the line of geology and paleozoology, and that he desired to continue it as opportunity and time permitted.

The Secretary continued that he was desirous of obtaining special endowments for the purpose of exploring and studying Central and South America. This would embrace all natural history, including zoology and botany, the securing of a knowledge of the natural resources, and also anthropological, including archeological investigation.

He particularly called attention to the fact that researches bearing upon the people of the Americas and their activities should be carried

on from a scientific point of view; also that it was desirable to state that the Smithsonian Institution was prepared to take charge of such researches, in accordance with its fundamental purposes—the increasing and diffusing of knowledge among men.

(*e*) PRESERVATION OF NATIONAL ANTIQUITIES.

The Secretary stated that under a recent action of the Secretaries of Agriculture, of War, and of the Interior, to whom had been delegated by law the authority to issue permits to secure antiquities from the lands under the control of the Government, an agreement had been reached to the effect that all applications for such permits should be referred to the Smithsonian Institution for recommendation.

(*f*) MINUTES AND NOTICE OF BUSINESS FOR MEETINGS.

The Secretary stated that it was his intention to send to each Regent, in advance of a meeting, a program of the business to come before such meeting, in order that the Regent might be familiar with the subject before his arrival at the meeting.

He also intended to send to those Regents absent from the meetings a copy of the Proceedings of such meetings, in order that all mght be kept constantly in touch with the business transacted, and also to send on the 1st of July, and perhaps quarterly, a statement of the financial condition of the Institution.

(*g*) RESIGNATION FROM THE RECLAMATION SERVICE AND THE GEOLOGICAL SURVEY.

The Secretary stated that his resignation as Director of the Reclamation Service had been transmitted in December to Secretary of the Interior Hitchcock, but that the latter had requested him to continue in charge until after March 4. Secretary Garfield had accepted the resignation to take effect March 8.

The Secretary further stated that his resignation as Director of the Geological Survey was placed in the hands of the President on January 25, but had not been acted upon, as the President wished him to remain in charge until after Mr. Garfield had made himself acquainted with the details of the administration of the Survey. The Secretary added that he hoped a new Director would be appointed by the 1st of April.

The Secretary, in answer to a question as to the purposes of the proposed South American expedition, stated that they were:

A general survey of the dominant geological, biological, and anthropological phenomena;

A study of material by specialists and the preparation of reports thereon; and

The publication and distribution of reports embodying the results of these investigations.

The Secretary added that the permanent committee had authority to accept gifts for such purposes, and he read the following paragraph, which he suggested would be advisable to be adopted in connection with all gifts to the Institution for specific purposes:

The specific objects named are considered most important, but the Board of Regents shall have full power, by a vote of two-thirds of their number, to modify the conditions and regulations under which the income from the fund may be dispensed, so as to insure that it shall always be applied in the manner best adapted to the changed conditions of the time; provided always that any modifications shall be in general accord with the purposes of the donor as hereinbefore expressed.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

FOR THE YEAR ENDING JUNE 30, 1907.

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the Institution, and the disbursement of the appropriations by Congress for the National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, the International Catalogue of Scientific Literature, and the ruin of Casa Grande for the year ending June 30, 1907, and balances of previous appropriations.

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1907.

The permanent fund of the Institution and the sources from which it has been derived are as follows:

DEPOSITED IN THE TREASURY OF THE UNITED STATES.

Bequest of Smithson, 1846		$515,169.00
Residuary legacy of Smithson, 1867		26,210.63
Deposit from savings of income, 1867		108,620.37
Bequest of James Hamilton, 1875	$1,000.00	
Accumulated interest on Hamilton fund, 1895	1,000.00	
		2,000.00
Bequest of Simeon Habel, 1880		500.00
Deposits from proceeds of sale of bonds, 1881		51,500.00
Gift of Thomas G. Hodgkins, 1891		200,000.00
Part of residuary legacy of Thomas G. Hodgkins, 1894		8,000.00
Deposit from savings of income, 1903		25,000.00
Residuary legacy of Thomas G. Hodgkins		7,918.69
Total amount of fund in the United States Treasury		944,918.69

HELD AT THE SMITHSONIAN INSTITUTION.

Registered and guaranteed bonds of the West Shore Railroad Company, part of legacy of Thomas G. Hodgkins (par value)	42,000.00
Total permanent fund	986,918.69

That part of the fund deposited in the Treasury of the United States bears interest at 6 per cent per annum, under the provisions of the act of August 10, 1846, organizing the Institution, and an act of Congress approved March 12, 1894. The rate of interest on the West Shore Railroad bonds is 4 per cent per annum.

United States 4 per cent registered bonds of the par value of $7,850, maturing July 1, 1907, were sold by your authority in February, 1907, and the proceeds, aggregating $7,918.69, were deposited in the Treasury of the United States to the credit of the permanent fund of the Institution.

Statement of receipts and disbursements from July 1, 1906, to June 30, 1907.

RECEIPTS.

Cash on deposit in the United States Treasury July 1, 1906		$10,184.13
Interest on fund deposited in the United States Treasury, due July 1, 1906, and January 1, 1907	$56,220.00	
Interest on West Shore Railroad bonds to January 1, 1907	1,680.00	
Repayments, rentals, publications, etc	5,016.35	
Proceeds from claims in litigation	1,292.56	
Interest on Hodgkins residuary fund	235.50	
		64,444.41
Proceeds from sale of $7,850 United States 4 per cent registered bonds, 1907, at 100⅞		7,918.69
Total receipts		82,547.23

DISBURSEMENTS.

Buildings, care and repairs	$4,543.24	
Furniture and fixtures	1,479.78	
General expenses:		
Salaries	$13,290.19	
Meetings	380.87	
Stationery	729.41	
Postage and telegrams	305.71	
Freight	194.40	
Incidentals	3,221.74	
	18,122.32	
Library:		
Purchase of books, binding, etc	668.68	
Salaries	1,015.00	
	1,683.68	
Publications and their distribution:		
Contributions to Knowledge	278.40	
Reports	961.39	
Miscellaneous Collections	2,165.36	
Publication supplies	214.64	
Special publications	156.52	
Salaries	5,127.00	
	8,903.31	
Explorations and researches	2,482.65	
Hodgkins specific fund:		
Researches and publications	3,289.93	

International Exchanges	$3,433.25	
International Catalogue of Scientific Literature	4,602.30	
Legal expenses	1,786.30	
Apparatus	35.21	
Gallery of Art	174.56	
		$49,936.53
Advances		100.00
United States Treasury:		
Deposited to credit of permanent fund		7,918.69
Balance June 30, 1907, deposited with the Treasurer of the United States		24,592.01
		82,547.23

By authority, your executive committee employed Mr. J. E. Bates, a certified public accountant, to audit the receipts and disbursements of the Smithsonian Institution during the period covered by this report. His certificate of examination supports the foregoing statement, and reads as follows:

WASHINGTON, D. C., *October 8, 1907.*

The Executive Committee, Board of Regents, Smithsonian Institution, Washington, D. C.

GENTLEMEN: I certify that I have examined the accounts of the Smithsonian Institution for the fiscal year ending June 30, 1907, and find the following cash statement to be correct:

July 1, 1906, balance on hand		$10,184.13
RECEIPTS.		
Total receipts for year ending June 30, 1907		72,363.10
Total		82,547.23
DISBURSEMENTS.		
Total disbursements for year		57,955.22
June 30, 1907, balance on hand		24,592.01
June 30, 1907, balance as per United States Treasurer's statement, after deducting all outstanding checks unpaid		24,592.01

Respectfully, yours,

(Signed) J. E. BATES.

All moneys received by the Smithsonian Institution from interest, sales, refunding of moneys temporarily advanced, or otherwise, are deposited with the Treasurer of the United States to the credit of the Institution, and all payments are made by checks signed by the Secretary.

The vouchers representing payments from the Smithsonian income during the year ending June 30, 1907, each of which bears the approval of the Secretary, or, in his absence, of the Acting Secretary, and a certificate that the materials and services charged were applied

to the purposes of the Institution, have been examined by the Auditor in connection with the books of the Institution, and found correct.

Your committee also presents the following statements in regard to the appropriations and expenditures for objects intrusted by Congress to the care of the Smithsonian Institution, based on expenditures by the disbursing agent and audited by the Auditor for the State and other Departments:

Detailed statement of disbursements from appropriations committed by Congress to the care of the Smithsonian Institution for the fiscal year ending June 30, 1907, and from balances of former years.

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For expenses of the system of international exchanges between the United States and foreign countries under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals" (sundry civil act, June 30, 1906)	$28,800.00

DISBURSEMENTS.

Salaries or compensation:		
1 Assistant Secretary, at $225 per month	$2,700.00	
1 clerk, at $150 per month	1,800.00	
1 clerk, at $125 per month	304.16	
1 clerk, at $125 per month	1,500.00	
1 clerk, at $116.66 per month	1,399.92	
1 clerk, at $80 per month	960.00	
1 clerk, at $80 per month	960.00	
1 clerk, at $70 per month	137.67	
1 clerk, at $70 per month	64.16	
1 clerk, at $70 per month	224.00	
1 clerk, at $65 per month	780.00	
1 clerk, at $50 per month	200.00	
1 stenographer, at $125 per month	1,500.00	
1 stenographer and typewriter, at $60 per month	166.00	
1 messenger, at $35 and $45 per month	142.00	
1 messenger boy, at $25 and $30 per month	330.00	
1 messenger boy, at $25 per month	300.00	
1 workman, at $70 per month	840.00	
1 skilled laborer, at $55 per month	660.00	
1 skilled laborer, at $30 per month	214.00	
1 agent, at $66.66⅔ per month	800.00	
1 agent, at $15 per month	180.00	
1 agent, at $75 per month	900.00	
Total salaries or compensation		$17,061.91

General expenses:			
Books	$156.75		
Boxes	737.55		
Freight, etc	6,916.07		
Furniture	621.77		
Postage	500.00		
Supplies, electricity, etc	361.95		
Stationery, etc	233.24		
		$9,527.33	
Total disbursements			$26,589.24
Balance July 1, 1907			2,210.76

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1906.

Balance July 1, 1906, as per last report $905.95

DISBURSEMENTS.

Boxes	$293.50	
Freight	542.64	
Stationery, books, etc	39.67	
Supplies	26.16	
Total disbursements		901.97
Balance July 1, 1907		3.98

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1905.

Balance July 1, 1906, as per last report $0.06

No disbursements.

Balance carried, under provisions of Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, June 30, 1907.

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For continuing ethnological researches among the American Indians and the natives of Hawaii, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, forty thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building" (sundry civil act, June 30, 1906) $40,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 chief, at $333.33 per month	$3,999.96	
1 ethnologist, at $250 per month	3,000.00	
2 ethnologists, at $200 per month	4,800.00	
2 ethnologists, at $133.33 per month	3,199.92	
2 ethnologists, at $125 per month	3,000.00	
1 illustrator, at $166.67 per month	2,000.04	
1 editor, at $100 per month	1,200.00	
1 editor and proof-reader, at $4.68 per day	402.48	

Salaries or compensation—Continued.		
1 clerk, at $125 per month	$425.00	
1 head clerk, at $100 per month	1,200.00	
2 clerks, at $100 per month	2,100.00	
1 clerk, at $100 per month and $3.33 per day	469.88	
1 librarian, at $100 per month	1,200.00	
1 typewriter, at $65 per month	448.51	
1 typewriter, at $60 per month	360.00	
1 assistant, at $60 per month	162.00	
1 messenger, at $55 per month	660.00	
1 skilled laborer, at $60 per month	720.00	
1 laborer, at $50 per month	600.00	
1 laborer, at $45 per month	540.00	
1 book-wrapper, at 30 cents per hour	173.40	
1 laborer, at $1.50 per day	43.50	
1 charwoman, at $1.50 per day	13.50	
Total salaries or compensation		$30,718.19
General expenses:		
Books, binding, etc	$547.90	
Drawings, maps, etc	326.60	
Freight, hauling, etc	96.25	
Furniture and fixtures	421.90	
Lighting	279.21	
Manuscript	717.95	
Miscellaneous	157.27	
Postage, telephone, and telegraph	138.84	
Rental	1,375.00	
Special services	725.57	
Specimens	24.50	
Stationery	843.82	
Supplies	538.24	
Travel and field expenses	2,154.96	
		8,348.01
Total disbursements		$39,066.20
Balance July 1, 1907		933.80

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1906.

Balance July 1, 1906, as per last report		$622.28
DISBURSEMENTS.		
Books	$15.17	
Freight	30.38	
Furniture and fixtures	30.15	
Lighting	92.96	
Miscellaneous	21.83	
Postage, telephone, and telegraph	29.41	
Special services	28.00	
Stationery	35.48	
Supplies	69.39	
Travel and field expenses	259.78	
Total disbursements		612.77
Balance July 1, 1907		9.51

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1905.

Balance July 1, 1906, as per last report $4.40

No disbursements.

Balance carried, under provisions of Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, June 30, 1907.

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, printing and publishing results of researches, not exceeding 1,500 copies, repairs and alterations of buildings, and miscellaneous expenses, $14,000" (sundry civil act, June 30, 1906) $14,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 acting director, at $225 per month	$2,700.00	
1 junior assistant, at $150 per month	1,800.00	
1 computer, at $83.33 per month	833.30	
1 computer, at $83.33 per month	480.53	
1 bolometric assistant, at $50 per month	116.67	
1 instrument-maker, at $100 per month	1,200.00	
1 clerk, at $125 per month	141.67	
1 clerk, at $125 per month	8.33	
1 stenographer, at $116.66 per month	1,392.14	
1 messenger boy, at $40 per month	480.00	
1 carpenter, at $91 per month	15.17	
1 fireman, at $60 per month	672.00	
1 skilled laborer, at $100 per month	50.00	
1 cleaner, at $1.25 per day	163.75	
1 cleaner, at $1 per day	18.00	
Total salaries or compensation		$10,071.56
General expenses:		
Apparatus	$405.65	
Books and binding	152.78	
Building repairs	267.00	
Castings	13.65	
Drawings, tables, etc	117.25	
Electricity, gas, etc	222.38	
Freight	76.32	
Furniture	42.54	
Lumber	4.16	
Postage, telephone, and telegraph	13.55	
Stationery	19.21	
Supplies, chemicals, tools, etc	160.42	
Travel and field expenses	495.55	
		1,990.46
Total disbursements		12,062.02
Balance July 1, 1907		1,937.98

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1906.

Balance July 1, 1906, as per last report		$2,246.08

DISBURSEMENTS.

Services of bolometric assistant, at $50 per month	$25.00	
Apparatus	94.65	
Books and binding	79.72	
Buildings, repairs, etc	599.00	
Electricity, gas, etc	292.60	
Freight	158.22	
Postage, telephone, and telegraph	2.35	
Supplies, chemicals, tools, etc	58.25	
Travel and field expenses	779.03	
Total disbursements		2,088.82
Balance, July 1, 1907		157.26

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1905.

Balance July 1, 1906, as per last report		$22.39

DISBURSEMENTS.

Supplies	$0.35	
Travel and field expenses	9.01	
Total disbursements		9.36
Balance		13.03

Balance carried, under provisions of Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, June 30, 1907.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE, SMITHSONIAN INSTITUTION, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For the cooperation of the United States in the work of the International Catalogue of Scientific Literature, including the preparation of a classified index catalogue of American scientific publications for incorporation in the International Catalogue, the expense of clerk hire, the purchase of necessary books and periodicals, and other necessary incidental expenses, five thousand dollars, the same to be expended under the direction of the Secretary of the Smithsonian Institution" (sundry civil act, June 30, 1906)	$5,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 chief assistant, at $125 and $150	$1,675.00	
1 classifier, at $90	1,080.00	
1 classifier, at $75	128.75	
1 clerk, at $125	54.17	
1 clerk, at $25, $50, and $60	512.50	
1 clerk, at $30 and $50	250.00	
1 cataloguer, at $60	191.00	
1 cataloguer, at $50	230.84	

Salaries or compensation—Continued.			
1 cataloguer, at $40	$40.00		
1 typewriter, at $50	58.33		
1 typewriter, at $50	149.99		
1 copyist, at $30	5.00		
1 messenger boy, at $25	100.00		
Total salaries or compensation		$4,475.58	
General expenses:			
Books	80.19		
Furniture and fixtures	169.69		
Postage, telephone, and telegraph	24.25		
Stationery	63.70		
Supplies	65.65		
		403.48	
Total disbursements			$4,879.06
Balance July 1, 1907			120.94

RUIN OF CASA GRANDE, ARIZONA, SMITHSONIAN INSTITUTION, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For protection of Casa Grande ruin, in Pinal County, near Florence, Ariz., and for excavation on the reservation, to be expended under the supervision of the Secretary of the Smithsonian Institution, three thousand dollars" (sundry civil act, June 30, 1906)	$3,000.00

DISBURSEMENTS.

Building supplies, subsistence, etc	$632.17	
Labor, team hire, etc	2,067.80	
Travel and field expenses	299.50	
Total disbursements		2,999.47
Balance July 1, 1907		.53

FURNITURE AND FIXTURES, NATIONAL MUSEUM, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees" sundry civil act, June 30, 1906	$20,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 superintendent, at $166.66	$999.96	
1 clerk, at $110	1,320.00	
1 shop foreman, at $90	1,080.00	
4 carpenters, at $85	3,145.00	
1 carpenter, at $3.35 per day	137.35	
1 carpenter, at $3.25 per day	81.25	
1 painter, at $70 and $75	822.50	
2 painters, at $75	271.25	

Salaries or compensation—Continued.		
1 painter's helper, at $55 and $70	$832.50	
1 skilled laborer, at $100	800.00	
1 skilled laborer, at $65	650.00	
1 workman, at $55	660.00	
6 laborers, at $1.50 per day	48.00	
Total salaries or compensation		$10,847.81
General expenses:		
Drawers, trays, boxes	2,057.60	
Frames, etc	28.75	
Glass	562.65	
Hardware	458.81	
Tools	46.03	
Cloth	6.38	
Lumber	1,066.79	
Paints, oils, etc	210.13	
Office and hall furniture, etc	1,083.11	
Flour	4.80	
Paper	36.30	
Special services	98.50	
Total general expenses		5,659.85
Total disbursements		$16,507.66
Balance July 1, 1907		3,492.34

FURNITURE AND FIXTURES, NATIONAL MUSEUM, 1906.

RECEIPTS.

Balance July 1, 1906, as per last report	$2,656.98

DISBURSEMENTS.

General expenses:		
Cloth, cotton, etc	$3.00	
Drawers, trays, boxes, etc	347.18	
Glass jars	219.23	
Hardware	77.35	
Lumber	281.19	
Office and hall furniture	344.70	
Paints, oils, etc	77.75	
Storage cases	895.65	
Total disbursements		2,246.05
Balance July 1, 1907		410.93

FURNITURE AND FIXTURES, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1906, as per last report	$88.68
Disbursements, none.	
Balance	88.68

Balance carried, under provisions of Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, June 30, 1907.

HEATING AND LIGHTING, NATIONAL MUSEUM, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For expenses of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum" (sundry civil act, June 30, 1906)	$18,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 engineer, at $125	$1,500.00	
1 telephone operator, at $70	821.33	
1 telephone operator, at $1.50 per day	66.75	
1 fireman, at $60	720.00	
1 blacksmith, at $60	720.00	
1 steam fitter, at $80	960.00	
1 plumber's assistant, at $65	777.83	
1 skilled laborer, at $100	300.00	
1 skilled laborer, at $80 and $4 per day	996.00	
1 skilled laborer, at $80	80.00	
2 laborers, at $45	1,080.00	
3 electrician's helpers, at $2.50 per day	156.25	
Total salaries or compensation		$8,178.16
General expenses:		
Coal and wood	4,676.17	
Electrical supplies	574.54	
Electricity	1,552.13	
Gas	301.83	
Heating supplies	198.77	
Rent of call boxes	110.00	
Special services	190.00	
Telegrams	5.26	
Telephones	389.34	
		7,998.04
Total disbursements		16,176.20
Balance July 1, 1907		1,823.80

HEATING AND LIGHTING, NATIONAL MUSEUM, 1906.

RECEIPTS.

Balance July 1, 1906, as per last report	$1,396.75

DISBURSEMENTS.

General expenses:	
Advertising	$8.10
Electrical supplies	389.53
Electricity	132.59
Gas	37.40
Heating supplies	303.65
Rent of call boxes	10.00

General expenses—Continued.		
Telegrams	$4.18	
Telephones	144.92	
Special services	122.00	
Total disbursements		$1,152.37
Balance July 1, 1907		244.38

HEATING AND LIGHTING, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1906, as per last report	$81.02
Disbursements, none.	
Balance	81.02

Balance carried, under provisions of Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, June 30, 1907.

PRESERVATION OF COLLECTIONS, NATIONAL MUSEUM, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, and all other necessary expenses, $180,000, of which sum $5,500 may be used for necessary drawings and illustrations for publications of the National Museum" (sundry civil act, June 30, 1906)	$180,000.00

DISBURSEMENTS.

Salaries or compensation:		
Scientific and administrative staff—		
1 assistant secretary, at $258.33 and $333.33	$3,399.96	
1 administrative assistant, at $291.66	3,499.92	
3 head curators, at $291.66	10,339.35	
2 curators, at $200	3,966.67	
1 associate curator, at $200	2,400.00	
1 curator, at $100	840.00	
5 assistant curators, at $160	7,808.83	
2 assistant curators, at $143.33	3,439.92	
1 assistant curator, at $130	1,560.00	
2 assistant curators, at $126.66	3,039.84	
2 assistant curators, at $125	1,562.50	
1 assistant curator, at $100 and $116.66	1,291.63	
2 assistant curators, at $110	2,574.00	
1 assistant curator, at $93.33	1,119.96	
1 second assistant curator, at $110	1,320.00	
1 chief of division, at $200	2,400.00	
1 editor, at $167	2,004.00	
1 editorial assistant, at $133.33	1,599.96	
1 registrar, at $167	2,004.00	

Salaries or compensation—Continued.		
Scientific and administrative staff—Continued.		
1 disbursing agent, at $125	$1,500.00	
1 assistant librarian, at $133.33	1,599.96	
1 aid, at $115	1,357.00	
1 aid, at $100	1,200.00	
1 aid, at $85	1,020.00	
2 aids, at $83.33	1,961.03	
2 aids, at $75	1,800.00	
4 aids, at $60	2,306.00	
1 aid, at $55	605.00	
1 assistant, at $90	162.00	
		$69,681.53
Preparators—		
1 photographer, at $175	2,100.00	
1 photographic assistant, at $50	450.00	
1 chief taxidermist, at $125	1,500.00	
1 taxidermist, at $100	1,200.00	
1 taxidermist, at $60	720.00	
1 taxidermist apprentice, at $25	300.00	
1 modeler, at $100	1,200.00	
1 osteologist, at $90	1,080.00	
1 preparator, at $125	1,500.00	
1 preparator, at $100	1,200.00	
1 preparator, at $95	991.17	
1 preparator, at $90	1,080.00	
1 preparator, at $85	345.67	
1 preparator, at $85	1,020.00	
1 preparator, at $80	960.00	
1 preparator, at $70	11.67	
1 preparator, at $60	720.00	
2 preparators, at $50	259.17	
1 preparator, at $45	535.50	
1 preparator, at $40	237.33	
2 preparators, at $25	301.67	
1 preparator, at $2.50 per day	340.00	
1 assistant preparator, at $45	539.25	
1 custodian, at $25	150.00	
1 classifier, at $100	1,200.00	
1 recorder, at $75	900.00	
1 recorder, at $70	840.00	
1 cataloguer, at $75	115.00	
1 cataloguer, at $60	720.00	
1 cataloguer, at $60 and $66.66	746.61	
1 cataloguer, at $50	331.95	
		23,594.99
Clerical staff—		
1 finance clerk, at $135	1,620.00	
1 property clerk, at $100	1,200.00	
1 document clerk, at $55	660.00	
1 clerk, at $125	1,054.17	
1 clerk, at $116.66	633.85	
2 clerks, at $100	1,850.00	
1 clerk, at $85	1,017.17	
4 clerks, at $80	3,492.67	
3 clerks, at $75	2,700.00	

Salaries or compensation—Continued.

Clerical staff—Continued.		
1 clerk, at $70	$840.00	
1 clerk, at $65	780.00	
4 clerks, at $60	2,013.00	
2 clerks, at $50	651.67	
1 clerk, at $35	420.00	
2 clerks, at $1.75 per day	95.38	
1 clerk and typewriter, at $75	900.00	
1 clerk and preparator, at $60 and $65	747.50	
1 botanical assistant, at $75	251.25	
1 stenographer, at $175	2,100.00	
1 stenographer, at $90	682.50	
1 stenographer, at $83.33	264.99	
1 stenographer, at $50	100.00	
1 stenographer and typewriter, at $100	1,200.00	
4 stenographers and typewriters, at $75	1,421.25	
5 stenographers and typewriters, at $60	807.50	
2 stenographers and typewriters, at $50	179.99	
4 typewriters, at $60	326.00	
7 typewriters, at $50	1,238.33	
1 botanical clerk, at $50	427.33	
1 messenger, at $35	79.33	
1 messenger, at $30	360.00	
1 messenger, at $25	7.50	
		$30,121.38
Buildings and labor—		
1 captain of watch, at $90	1,080.00	
2 lieutenants of watch, at $70	1,680.00	
1 watchman, at $65	780.00	
24 watchmen, at $60	15,696.00	
4 watchmen, at $55	1,084.09	
1 special watchman, at $3 per day	21.00	
1 special watchman, at $2 per day	14.00	
1 foreman, at $75	900.00	
1 workman, at $50	591.66	
1 skilled laborer, at $60	266.00	
1 skilled laborer, at $55	660.00	
3 skilled laborers, at $50	951.67	
1 skilled laborer, at $45	396.00	
3 skilled laborers, at $40	541.66	
6 skilled laborers, at $30	1,977.50	
3 skilled laborers, at $25	405.00	
2 skilled laborers, at $1.50 per day	512.50	
1 classified laborer, at $60	120.00	
2 classified laborers, at $47	705.00	
1 laborer, at $47	564.00	
19 laborers, at $40	7,495.32	
2 laborers, at $35	710.83	
4 laborers, at $1.50 per day	111.00	
2 laborers, at $1 per day	46.00	

Salaries or compensation—Continued.			
Buildings and labor—Continued.			
9 cleaners, at $35	$2,637.83		
1 attendant, at $40	50.67		
1 attendant, at $35	346.50		
1 attendant, at $1.25 per day	226.25		
1 seamstress, at $1.50 per day	21.00		
		$40,591.48	
Total salaries or compensation		163,989.38	
General expenses:			
Drawings and illustrations	1,556.60		
Freight and cartage	1,016.12		
Special services	1,049.81		
Specimens	2,349.87		
Stationery	909.69		
Supplies	4,268.03		
Traveling expenses	1,170.69		
		12,320.81	
Total disbursements			$176,310.19
Balance July 1, 1907			3,689.81

PRESERVATION OF COLLECTIONS, NATIONAL MUSEUM, 1906.

RECEIPTS.

Balance July 1, 1906, as per last report		$4,158.60
By disallowance in voucher No. 291		.10
		4,158.70

DISBURSEMENTS.

Drawings and illustrations	$221.78	
Freight and cartage	273.34	
Special services	130.41	
Specimens	939.57	
Stationery	327.56	
Supplies	1,191.05	
Traveling expenses	49.80	
Total disbursements		3,133.51
Balance July 1, 1907		1,025.19

PRESERVATION OF COLLECTIONS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1906, as per last report	$571.30

DISBURSEMENTS.

General expenses:		
Freight	$0.25	
Special services	.52	
Specimens	35.70	
Total disbursements		36.47
Balance		534.83

Balance carried, under provisions of Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, June 30, 1907.

BOOKS, NATIONAL MUSEUM, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For purchase of books, pamphlets, and periodicals, for reference in the National Museum" (sundry civil act, June 30, 1906)	$2,000.00

DISBURSEMENTS.

Books, pamphlets, and periodicals	658.30
Balance July 1, 1907	1,341.70

BOOKS, NATIONAL MUSEUM, 1906.

RECEIPTS.

Balance July 1, 1906, as per last report	$737.82

DISBURSEMENTS.

Books, pamphlets, and periodicals	679.13
Balance July 1, 1907	58.69

BOOKS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1906, as per last report	$60.27

DISBURSEMENTS.

Books and periodicals	53.53
Balance	6.74

Balance carried, under provisions of Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, June 30, 1907.

BUILDING REPAIRS, NATIONAL MUSEUM, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material" (sundry civil act, June 30, 1906)	$15,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 superintendent, at $100.00		$833.96
1 foreman, at $80		1,080.00
1 carpenter, at $85		680.00
2 painters, at $75		142.50
2 tinners, at $70		560.00
1 classified laborer, at $80		960.00
1 skilled laborer, at $80 and $40		670.00
1 skilled laborer, at $1.75 per day		3.50
1 skilled laborer, at $1.50 per day		192.00
1 laborer, at $45		540.00
5 laborers, at $1.50 per day		283.50
Total salaries or compensation	6,086.46	

General expenses:		
Cloth	$24.81	
Fireproof blocks, cement, plaster, bricks	465.54	
Glass	60.93	
Hardware and tools	189.87	
Lumber	189.30	
Paints, oils, brushes, etc	373.43	
Plumbing material	27.97	
Plastering	103.60	
Repairs to roofs (by contract)	6,802.00	
Sectional ladders, etc	35.00	
Special services	2.00	
Steel beams	8.55	
		$8,283.00
Total disbursements		$14,369.46
Balance July 1, 1907		630.54

BUILDING REPAIRS, NATIONAL MUSEUM, 1906.

RECEIPTS.

Balance July 1, 1906, as per last report	$4,793.48

DISBURSEMENTS.

General expenses:		
Hardware, etc	$5.70	
Lime, sand, etc	2.85	
Paints, oils, etc	13.95	
Repairs to roofs (by contract)	4,665.00	
Total disbursements		4,687.50
Balance July 1, 1907		105.98

BUILDING REPAIRS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1906, as per last report	$307.59
Disbursements, none.	
Balance	307.59

Balance carried, under provisions of the Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, June 30, 1907.

POSTAGE, NATIONAL MUSEUM, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For postage stamps and foreign postal cards for the National Museum" (sundry civil act, June 30, 1906)	$500.00

DISBURSEMENTS.

For postage stamps and cards	500.00

RENT OF WORKSHOPS, NATIONAL MUSEUM, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For rent of workshops and temporary storage quarters for the National Museum" (sundry civil act, June 30, 1906)	$4,580.00

DISBURSEMENTS.

Rent of workshops:		
431 Ninth street southwest, 12 months, at $166.66	$1,999.92	
217 Seventh street southwest, 12 months, at $105	1,260.00	
309 and 313 Tenth street southwest, 12 months, at $80	960.00	
915 Virginia avenue (rear), 12 months, at $30	360.00	
Total disbursements		4,579.92
Balance July 1, 1907		.08

RENT OF WORKSHOPS, NATIONAL MUSEUM, 1906.

RECEIPTS.

Balance July 1, 1906, as per last report	$0.08
Disbursements, none.	
Balance July 1, 1907	.08

RENT OF WORKSHOPS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1906, as per last report	$0.08
Disbursements, none.	
Balance	.08

Balance carried, under provisions of Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, June 30, 1907.

NATIONAL MUSEUM, TRANSPORTATION OF EXHIBITS ACQUIRED FROM THE LOUISIANA PURCHASE EXPOSITION.

RECEIPTS.

Balance July 1, 1906, as per last report	$1,171.33
Disbursements, none.	
Balance	1,171.33

Balance carried, under provisions of Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, March 3, 1907.

PRINTING AND BINDING, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For the Smithsonian Institution, for printing and binding the annual reports of the Board of Regents, with general appendixes, $10,000; under the Smithsonian Institution, for the annual reports of the National Museum, with general appendixes, and for the Annual Report of the American Historical Association, and for *printing* labels and blanks, and for the Bulletins and Proceedings of	

the National Museum, the editions of which shall not exceed 4,000 copies, and binding, in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library, $39,000; for the annual reports and bulletins of the Bureau of American Ethnology, $21,000; in all, $70,000" (sundry civil act, June 30, 1906)..... $70,000.00

DISBURSEMENTS.

Reports of the Board of Regents		$8,127.98
Reports and Bulletins of the Bureau of American Ethnology		19,831.76
National Museum:		
Reports 1905 and 1906	$3,502.72	
Bulletins	15,134.63	
Proceedings	6,969.25	
Miscellaneous blanks	953.58	
Miscellaneous binding	1,694.33	
Branch Printing Office	841.68	
National Herbarium	5,122.94	
Report American Historical Association	4,761.34	
		38,980.47
Total disbursements		66,940.21
Balance July 1, 1907		3,059.79

NATIONAL ZOOLOGICAL PARK, 1907.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1907, "For continuing the construction of roads, walks, bridges, water supply, sewerage, and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals; including salaries or compensation of all necessary employees, the purchase of necessary books and periodicals, the printing and publishing of operations, not exceeding 1,500 copies, and general incidental expenses not otherwise provided for, including purchase, maintenance, and driving of horses and vehicles required for official purposes, $95,000" (sundry civil act, June 30, 1906)..... $95,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 superintendent, at $275 per month	$3,300.00	
1 assistant superintendent, at $166.66 per month	1,999.92	
1 clerk, at $125 per month	1,012.50	
1 clerk, at $125 per month	1,500.00	
1 stenographer, at $83.33 per month	999.96	
1 messenger, at $60, and as copyist, at $60 per month	570.00	
1 messenger boy, at $30 per month	71.00	
1 messenger boy, at $30 per month	16.00	

Salaries or compensation—Continued.		
1 messenger boy, at $1 per day	$47.00	
1 head keeper, at $125 per month	1,500.00	
11 keepers, at $65 per month	8,393.67	
2 keepers, at $62.50 per month	1,500.00	
2 keepers, at $60 per month	1,436.00	
1 storekeeper, at $65 per month	780.00	
1 sergeant of watch, at $60 per month	720.00	
1 watchman, at $65 per month	780.00	
3 watchmen, at $60 per month	2,160.00	
1 messenger, at $45 per month, and as watchman, at $50 per month	585.00	
1 attendant, at $22.50 per month	270.00	
1 attendant, at 75 cents per day	14.25	
Total salaries or compensation		$27,655.30
General expenses:		
Buildings	1,362.08	
Building material	1,529.15	
Fencing, cage material, etc	696.48	
Food for animals	12,172.36	
Freight	379.42	
Fuel	1,984.43	
Lighting	28.93	
Lumber	1,121.19	
Machinery, tools, etc	546.82	
Miscellaneous	1,305.72	
Paints, oils, glass, etc	613.13	
Postage, telephone, and telegraph	219.90	
Purchase of animals	3,921.40	
Road material and grading	1,102.95	
Stationery, books, etc	252.74	
Travel and field expenses	203.44	
Trees, plants, etc	30.45	
Water supply, sewerage, etc	345.73	
Total miscellaneous		27,816.32
Wages of mechanics and laborers and hire of teams in constructing buildings and inclosures, laying water pipes, building roads, gutters, and walks, planting trees, and otherwise improving the grounds:		
1 machinist, at $100 per month	1,200.00	
1 foreman, at $75 per month	900.00	
1 blacksmith, at $3 per day and $65 per month	686.00	
1 assistant blacksmith, at $60 per month	720.00	
1 tinner, at $3.50 per day	178.50	
1 carpenter, at $85 per month	1,020.00	
1 carpenter, at $3 per day	40.50	
1 painter, at $3 per day	110.25	
2 classified laborers, at $65 per month	1,560.00	
1 classified laborer, at $60 per month	720.00	

Wages of mechanics and laborers, etc.—Continued.		
3 classified laborers, at $2 per day	$2,020.00	
1 classified laborer, at $1.75 per day	631.75	
4 skilled laborers, at $1.75 per day	280.90	
1 workman, at $65 per month	780.00	
2 laborers, at $55 per month	1,307.18	
1 laborer, at $45 per month	516.01	
1 laborer, at $40 per month	444.00	
1 laborer, at $2.25 per day	703.13	
2 laborers, at $2 per day	1,409.00	
3 laborers, at $2 per day	2,046.00	
16 laborers, at $1.75 per day	5,442.68	
39 laborers, at $1.50 per day	6,256.98	
1 laborer, at $1 per day	224.38	
8 helpers, at 75 cents per day	374.09	
2 water boys, at 50 cents per day	63.39	
2 wagons and teams, at $3.50 per day	1,005.39	
8 horses and carts, at $1.75 per day	634.40	
Total wages of mechanics, etc		$31,274.53
Total disbursements		$86,746.15
Balance July 1, 1907		8,253.85

NATIONAL ZOOLOGICAL PARK, 1906.

Balance July 1, 1906, as per last report $4,812.05

DISBURSEMENTS.

Buildings	$310.29	
Building material	830.91	
Fencing, cage material, etc	12.50	
Food for animals	1,434.91	
Freight and transportation of animals	1,024.46	
Fuel	.75	
Lighting	5.11	
Lumber	70.94	
Machinery, tools, etc	18.40	
Miscellaneous	193.10	
Paints, oils, glass, etc	60.34	
Postage, telephone, and telegraph	70.93	
Purchase of animals	105.28	
Road material and grading	48.68	
Stationery, books, printing, etc	53.72	
Trees, plants, etc	3.20	
Water supply, sewerage, etc	56.72	
Total disbursements		4,300.24
		511.81
To amount of disallowance in voucher No. 145		.99
Balance July 1, 1907		512.80

NATIONAL ZOOLOGICAL PARK, 1905.

Balance July 1, 1906, as per last report	$151.34

DISBURSEMENTS.

Surveying, plans, etc	150.00
Balance	1.34

Balance carried, under provisions of Revised Statutes, section 3691, by the Treasury Department to the credit of the surplus fund, June 30, 1907.

RECAPITULATION.

The total amount of funds administered by the Institution during the year ending June 30, 1907, appears from the foregoing statements to have been as follows:

SMITHSONIAN INSTITUTION.

From balance July 1, 1906	$10,184.13	
From receipts to June 30, 1907	72,363.10	
		$82,547.23

APPROPRIATIONS COMMITTED BY CONGRESS TO THE CARE OF THE INSTITUTION.

International Exchanges—Smithsonian Institution:		
From balance of 1905	$0.06	
From balance of 1906	905.95	
From appropriation for 1907	28,800.00	
		$29,706.01
American Ethnology—Smithsonian Institution:		
From balance of 1905	4.40	
From balance of 1906	622.28	
From appropriation for 1907	40,000.00	
		40,626.68
Astrophysical Observatory—Smithsonian Institution:		
From balance of 1905	22.39	
From balance of 1906	2,246.08	
From appropriation for 1907	14,000.00	
		16,268.47
International Catalogue of Scientific Literature—Smithsonian Institution:		
From appropriation for 1907		5,000.00
Ruin of Casa Grande, Arizona—Smithsonian Institution:		
From appropriation for 1907		3,000.00
Furniture and fixtures—National Museum:		
From balance of 1905	88.68	
From balance of 1906	2,656.98	
From appropriation for 1907	20,000.00	
		22,745.66
Heating and lighting—National Museum:		
From balance of 1905	81.02	
From balance of 1906	1,396.75	
From appropriation for 1907	18,000.00	
		19,477.77

Preservation of collections—National Museum:		
From balance of 1905	$571.30	
From balance of 1906	4,158.70	
From appropriation for 1907	180,000.00	
		$184,730.00
Books—National Museum:		
From balance of 1905	60.27	
From balance of 1906	737.82	
From appropriation for 1907	2,000.00	
		2,798.09
Building repairs—National Museum:		
From balance of 1905	307.59	
From balance of 1906	4,793.48	
From appropriation for 1907	15,000.00	
		20,101.07
Postage—National Museum:		
From appropriation for 1907		500.00
Rent of workshops—National Museum:		
From balance of 1905	.08	
From balance of 1906	.08	
From appropriation for 1907	4,580.00	
		4,580.16
Transportation of exhibits acquired from the Louisiana Purchase Exposition—National Museum:		
From balance of appropriation		1,171.33
Printing and binding—Smithsonian Institution:		
From appropriation for 1907		70,000.00
National Zoological Park:		
From balance of 1905	151.34	
From balance of 1906	4,812.05	
From appropriation for 1907	95,000.00	
		99,963.39

SUMMARY.

Smithsonian Institution		$82,547.23
International Exchanges		29,706.01
American Ethnology		40,626.68
Astrophysical Observatory		16,268.47
International Catalogue of Scientific Literature		5,000.00
Ruin of Casa Grande, Arizona		3,000.00
National Museum:		
Furniture and fixtures	$22,745.66	
Heating and lighting	19,477.77	
Preservation of collections	184,730.00	
Books	2,798.09	
Building repairs	20,101.07	
Postage	500.00	
Rent of workshops	4,580.16	
Transportation of exhibits acquired from the Louisiana Purchase Exposition	1,171.33	
		256,104.08
Printing and binding		70,000.00
National Zoological Park		99,963.39
		603,215.86

Statement of regular income from the Smithsonian fund available for use during the year ending June 30, 1908.

Balance June 30, 1907		$24,592.01
Interest due and receivable July 1, 1907	$28,247.01	
Interest due and receivable January 1, 1908	28,347.56	
Interest, West Shore Railroad bonds, due July 1, 1907	840.00	
Interest, West Shore Railroad bonds, due January 1, 1908	840.00	
		58,274.57
Total available for year ending June 30, 1908		82,866.58

Respectfully submitted.

J. B. HENDERSON,
ALEXANDER GRAHAM BELL,
JOHN DALZELL,
Executive Committee.

WASHINGTON, D. C., *January 18, 1908.*

ACTS AND RESOLUTIONS OF CONGRESS RELATIVE TO THE SMITHSONIAN INSTITUTION, ETC.

[Continued from previous reports.]

[Fifty-ninth Congress, second session.]

SMITHSONIAN INSTITUTION.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the vacancy in the Board of Regents of the Smithsonian Institution, of the class other than Members of Congress, shall be filled by the reappointment of George Gray, a citizen of Delaware, whose term expired January fourteenth, nineteen hundred and seven. (Approved January 21, 1907; Statutes, XXXIV, 1419.)

For the Smithsonian Institution, for printing and binding the Annual Reports of the Board of Regents, with general appendixes, ten thousand dollars; under the Smithsonian Institution, for the Annual Reports of the National Museum, with general appendixes, and for printing labels and blanks, and for the Bulletins and Proceedings of the National Museum, the editions of which shall not exceed four thousand copies, and binding, in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library, thirty-three thousand dollars; for the Annual Reports and Bulletins of the Bureau of American Ethnology, twenty-one thousand dollars; for miscellaneous printing and binding for the International Exchanges, two hundred dollars; the International Catalogue of Scientific Literature, one hundred dollars; the National Zoological Park, two hundred dollars; and the Astrophysical Observatory (including the publishing of results of researches, not exceeding one thousand five hundred copies), two thousand dollars; and for the Annual Report of the American Historical Association, seven thousand dollars; in all, seventy-three thousand five hundred dollars. (Approved March 4, 1907; Statutes, XXXIV, 1367.)

SMITHSONIAN DEPOSIT [LIBRARY OF CONGRESS]: For custodian, one thousand five hundred dollars; assistant, one thousand four hundred

dollars; messenger, seven hundred and twenty dollars; messenger boy, three hundred and sixty dollars; in all, three thousand nine hundred and eighty dollars. (Approved February 26, 1907; Statutes, XXXIV, 949.)

INTERNATIONAL EXCHANGES.

For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, thirty-two thousand dollars. (Approved March 4, 1907; Statutes, XXXIV, 1310.)

NAVAL OBSERVATORY: For repairs to buildings, fixtures, and fences, furniture, gas, chemicals, and stationery, freight (including transmission of public documents through the Smithsonian exchange), foreign postage, and expressage, plants, fertilizers, and all contingent expenses, two thousand five hundred dollars. (Approved February 26, 1907; Statutes, XXXIV, 971.)

BUREAU OF AMERICAN ETHNOLOGY.

For continuing ethnological researches among the American Indians and the natives of Hawaii, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, forty thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building.

For protection of Casa Grande Ruin, in Pinal County, near Florence, Arizona, and for excavation on the reservation, to be expended under the supervision of the Secretary of the Smithsonian Institution, three thousand dollars.

(Approved March 4, 1907; Statutes, XXXIV, 1310.)

For American Ethnology, Smithsonian Institution, thirty-six dollars and ninety-nine cents. (Approved March 4, 1907; Statutes, XXXIV, 1403.)

ASTROPHYSICAL OBSERVATORY.

For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, repairs and alterations of buildings and miscellaneous expenses, thirteen thousand dollars. (Approved March 4, 1907; Statutes, XXXIV, 1310.)

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

For the cooperation of the United States in the work of the International Catalogue of Scientific Literature, including the preparation of a classified index catalogue of American scientific publications for incorporation in the International Catalogue, the expense of clerk hire, the purchase of necessary books and periodicals, and other necessary incidental expenses, five thousand dollars, the same to be expended under the direction of the Secretary of the Smithsonian Institution. (Approved March 4, 1907; Statutes, XXXIV, 1310.)

NATIONAL MUSEUM.

For completing the construction of the building for the National Museum, and for each and every purpose connected with the same, one million two hundred and fifty thousand dollars: *Provided*, That if the superintendent of buildings and grounds, Library of Congress, now in charge of the construction of the new Museum building and the disbursing of all appropriations made for the work, be at any time incapacitated to continue in such charge, the Board of Regents of the Smithsonian Institution is hereby empowered to take charge of the construction and to disburse appropriations made for the same.

For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees, twenty thousand dollars.

For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum, eighteen thousand dollars.

For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, and all other necessary expenses, one hundred and ninety thousand dollars, of which sum five thousand five hundred dollars may be used for necessary drawings and illustrations for publications of the National Museum.

For purchase of books, pamphlets, and periodicals for reference in the National Museum, two thousand dollars.

For repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material, fifteen thousand dollars.

For rent of workshops and temporary storage quarters for the National Museum, four thousand five hundred and eighty dollars.

For postage stamps and foreign postal cards for the National Museum, five hundred dollars.

(Approved March 4, 1907; Statutes, XXXIV, 1311.)

NATIONAL ZOOLOGICAL PARK.

For continuing the construction of roads, walks, bridges, water supply, sewerage and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals; including salaries or compensation of all necessary employees, and general incidental expenses not otherwise provided for, including purchase, maintenance, and driving of horses and vehicles required for official purposes, ninety-five thousand dollars; one half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States.

For reconstructing and repairing roadways and walks, fifteen thousand dollars.

(Approved March 4, 1907; Statutes, XXXIV, 1311.)

JAMESTOWN TERCENTENNIAL EXPOSITION.

* * * * * * *

That April twenty-sixth, nineteen hundred and seven, is hereby fixed as the date for the opening of said celebration inaugurated by the Act of Congress approved March third, nineteen hundred and five, and that November thirtieth, nineteen hundred and seven, is hereby fixed as the date for the closing of the said celebration, and said dates shall apply to the participation of the United States and foreign countries in said celebration and in said exposition, as provided for by the Acts of Congress approved March third, nineteen hundred and five, and June thirtieth, nineteen hundred and six. (Approved February 9, 1907; Statutes, XXXIV, 887.)

AMENDMENTS TO GENERAL PRINTING ACT.

* * * Any Executive Department, bureau, board, or independent office of the Government submitting reports or documents in response to inquiries from Congress shall submit therewith an estimate of the probable cost of printing to the usual number. Nothing in this paragraph relating to estimates shall apply to reports or documents not exceeding fifty pages.

* * * If the publication so ordered be an annual report or serial publication originating in or prepared by an Executive Department, bureau, office, commission, or board, it shall not be numbered in the document or report series of either House of Congress, but shall be designated by title, as hereinafter provided. Of all Department reports required by law to be printed, the usual number shall be printed concurrently with the departmental edition.

* * * In the binding of Congressional numbered documents and reports, and Departmental publications furnished for distribution to State and Territorial libraries entitled by law to receive them, every publication of sufficient size on any one subject shall hereafter be bound separately, and receive the title suggested by the subject of the volume; and the others, if of a general public character, shall be arranged in convenient volumes and bound in a manner as directed by the Joint Committee on Printing; and those not of a general public character shall be delivered to the depositories in unbound form. * * *

That in the printing of any document or report, or any publication authorized by law to be printed, or hereafter authorized to be printed, for distribution by Congress, the whole number of copies of which shall not have been ordered within two years from the date of the original order, the authority to print shall lapse, except as orders for subsequent editions may be approved by the Joint Committee on Printing, and then in no instance shall the whole number exceed the number originally authorized by law.

(Approved March 1, 1907; Statutes, XXXIV, 1013, 1014.)

REPORT

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

CHARLES D. WALCOTT,

FOR THE YEAR ENDING JUNE 30, 1907.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit a report showing the operations of the Institution during the year ending June 30, 1907, including the work placed under its direction by Congress in the United States National Museum, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the Regional Bureau of the International Catalogue of Scientific Literature, and the excavations on the Casa Grande Reservation.

In the body of this report there is given a general account of the affairs of the Institution, while the appendix presents a more detailed statement by those in direct charge of the different branches of the work. Independently of this the operations of the National Museum and the Bureau of American Ethnology are fully treated in separate volumes. The scientific work of the Astrophysical Observatory, covering its researches for the past five years, will be described in Volume II of the Annals of the Observatory.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

By act of Congress approved August 10, 1846, the Smithsonian Institution was created an Establishment. Its statutory members are "the President, the Vice-President, the Chief Justice, and the heads of the Executive Departments."

As organized on June 30, 1907, the establishment consisted of the following ex officio members:

THEODORE ROOSEVELT, *President of the United States.*

CHARLES W. FAIRBANKS, *Vice-President of the United States.*

MELVILLE W. FULLER, *Chief Justice of the United States.*
ELIHU ROOT, *Secretary of State.*
GEORGE B. CORTELYOU, *Secretary of the Treasury.*
WILLIAM H. TAFT, *Secretary of War.*
CHARLES J. BONAPARTE, *Attorney-General.*
GEORGE VON L. MEYER, *Postmaster-General.*
VICTOR H. METCALF, *Secretary of the Navy.*
JAMES R. GARFIELD, *Secretary of the Interior.*
JAMES WILSON, *Secretary of Agriculture.*
OSCAR S. STRAUS, *Secretary of Commerce and Labor.*

THE BOARD OF REGENTS.

The Board of Regents consists of the Vice-President and the Chief Justice of the United States as ex officio members, three members of the Senate, three members of the House of Representatives, and six citizens, "two of whom shall be residents of the city of Washington, and the other four shall be inhabitants of some State, but no two of them of the same State."

The following appointments and reappointments of Regents were made during the year: By appointment of the Speaker, December 3, 1906, Representative James R. Mann in place of Representative R. R. Hitt, deceased; by joint resolution of Congress approved January 21, 1907, the Hon. George Gray to succeed himself; by appointment of the Vice-President on March 4, 1907, Senator S. M. Cullom and Senator A. O. Bacon to succeed themselves. On January 23, 1907, the Hon. John Dalzell was elected a member of the executive committee to fill the vacancy created by the death of Mr. Hitt.

It is with deep regret that I have to record the death of Representative Robert R. Hitt on September 20, 1906. Mr. Hitt was a member of the Board of Regents on the part of the House of Representatives for more than thirteen years.

The membership of the Board at the end of the fiscal year was as follows: The Hon. Melville W. Fuller, Chief Justice of the United States, Chancellor; the Hon. Charles W. Fairbanks, Vice-President of the United States; Senator S. M. Cullom; Senator Henry Cabot Lodge; Senator A. O. Bacon; Representative John Dalzell; Representative James R. Mann; Representative W. M. Howard; Dr. James B. Angell, of Michigan; Dr. Andrew D. White, of New York; the Hon. J. B. Henderson, of Washington, D. C.; Dr. A. Graham Bell, of Washington, D. C.; the Hon. Richard Olney, of Massachusetts; and the Hon. George Gray, of Delaware.

At a meeting of the Board of Regents held March 12, 1903, the following resolution was adopted:

Resolved, That in addition to the prescribed meeting held on the fourth Wednesday in January, regular meetings of the Board shall be held on the

Tuesday after the first Monday in December and on the 6th day of March, unless that date falls on Sunday, when the following Monday shall be substituted.

In accordance with this resolution, the Board met on December 4, 1906; January 23, 1907, and March 6, 1907. The proceedings of the Board at these meetings will be found in its annual report to Congress.

GENERAL CONSIDERATIONS.

It is with a deep sense of responsibility that I have assumed the office of Secretary, and I greatly appreciate the honor conferred by the Regents in electing me to the position. Once before, as acting assistant secretary, I had administrative charge for nearly two years of a most important branch of the Institution's work, the United States National Museum. I have been associated with the scientific work of the Museum for almost a quarter of a century, and for many years have been in close personal contact with other important branches of the Institution's activities.

I fully recognize the obligation resting upon the man who holds the position which has been successively occupied by Joseph Henry, Spencer F. Baird, and Samuel P. Langley. By a wise and conservative policy, maintaining at once the independence of the Smithsonian fund and yet freely cooperating with the Government in securing aid in the development of its branches, the Institution has reached a position of eminence far beyond what might have been expected from the comparatively small endowment which it possesses. It has, moreover, on numerous occasions conducted in its initial stages scientific work that has proven to be of great practical value, and when the experimental stage was passed and their economic utility had been demonstrated, the organizations and results obtained were turned over to the Government. Through one or another of its agencies the name Smithsonian Institution has been brought to the attention of scientific workers in this country and in other lands and to those educated people generally who, though without special training in science, desire to keep abreast of the progress of the world. It has abandoned projects which other institutions had undertaken, on the theory that there was plenty of work for all to do, and it has aided investigators throughout the United States and indeed in foreign lands as heartily as it has supported the work of its own staff.

In other words, I feel that I have come to an establishment unselfish in its aims and willing to help all men in furtherance of the objects for which it was founded—an institution devoted fully to the progress and spread of knowledge in every field without limitation to one branch of science or to all science, but having within its purview the elevation of mankind through the increase and spread of knowledge. The heads of the Institution thus far have been specialists

trained in different branches of knowledge. Henry was a physicist, Baird a naturalist, Langley an astronomer and physicist. While they were carrying on the general affairs of the Institution each of these men pursued particular investigations. No one of them, however, allowed his judgment to be biased by the limitations of his own specialty. I hope to follow in the footsteps of these men. In addition to guiding the affairs of the Institution, I expect to carry on research work in geology and paleontology, and to prepare some memoirs on these subjects which have occupied a large part of my life. Such research work produces a greater sympathy and understanding of the special work of others; as in the past, it will in no wise tend to alter the universal character of the Institution or to limit my interest in all departments of research.

My predecessors have so wisely and so economically administered the affairs of the Institution that I have come to a well-equipped establishment with its traditions and its policy founded upon right principles, and they do not appear to be susceptible of material improvement. I shall, however, through special agencies created from time to time, carefully study the workings of the Institution and of all of its branches with the purpose of satisfying myself as to existing conditions and methods, and in order to retain a practical and high standard of administration.

Speaking for the Institution proper, it appears to me that it has been developed to the full extent possible under its present endowment. It can not have escaped the attention of observers that, in the sixty years and more in which the Smithsonian Institution has existed, few additions have come to its funds. While money has been freely given for the enlargement of existing institutions of learning and research and even more has been forthcoming for the establishment of new ones, the fund of this Institution remains at about $1,000,000, but a little over double what it was at its foundation. The generous men and women who have supported science and art in this country have possibly not considered the fact that there is necessarily a waste in the founding of a new organization. Moreover, a much greater amount of good can often be accomplished by financially aiding an existing institution than by creating a new one of the same type. That this Institution has popularity can not be doubted, but it has seemed to suffer from one of its greatest advantages, namely, its connection with the Government. Being a ward of the nation, it is thought by the public to be a recipient of generous Congressional appropriations. While this is in a measure true for the branches in charge of the Institution, yet no provision is made by Congress for carrying on the activities of the Institution proper. I think this is a very sound condition, but feel that it should be made

sufficiently clear to all who may be interested or become interested in the Institution and its work.

There are numerous projects actually awaiting systematic development that can not properly receive support from the Government and which from their nature might be advantageously conducted under the charge of the Institution; these include, among others, the scientific exploration of large areas of Central and South America; the investigation of various problems connected with the deposition of ores; investigations in regard to the production of petroleum by artificial means; the study upon a large scale of anthropological and ethnological problems having direct bearing on the future American people; the systematic study of seismological (earthquake) phenomena. Although it may be held that the practical demonstration of these problems will be provided for elsewhere, it must be borne in mind that few scientific activities are without some ultimate relation to practical affairs and that researches bearing directly upon the activities of the people and natural productions must be carried on from the scientific point of view.

In order to further develop, if possible, that part of the Institution's programme which has to do with the diffusion of knowledge, I have tentatively initiated a plan which will greatly enlarge the scope of the Institution's work in this respect. The carefully selected general appendix to the Smithsonian Annual Report is the principal means, aside from the International Exchange Service, whereby the Institution diffuses knowledge. Some 10,000 copies of these Reports are printed, a large majority of which are placed in public libraries, where they are accessible to many readers, while but a small proportion can be sent to individuals. I have accordingly initiated a plan of having prepared, in popular language, abstracts of the publications of the Institution and sometimes special articles on the investigations in progress by the Institution. These have been distributed to the daily newspapers, which, in the main, have made use of them. In this way the material in the Reports and other publications of the Institution, as well as the knowledge of current investigations, have been rendered accessible to millions of readers.

Although I assumed the office of Secretary on the 31st of January, 1907, I continued, at the request of the President, the direction of affairs of the Geological Survey, with which, however, my connection as Director terminated on April 30.

In order that my time might be as free as possible for the affairs of the Institution and for research work, I considered the question of severing my relationship with the Carnegie Institution of Washington, of which I am a member of the board of trustees and of the

executive committee. After conferring, however, with my colleagues on that committee and with the members of the Board of Regents, it was considered on all hands desirable and as productive of harmonious and useful cooperation between two kindred institutions that I should retain my membership of the board of trustees and of the executive committee of the Carnegie Institution.

During the year the Smithsonian Institution cooperated with and received the aid of most of the Government Departments, though I may especially mention the Departments of State, Agriculture, Interior, and Commerce and Labor, and the valuable advice and assistance received from the Department of Justice. Through its Exchange Service, its publications, its collections, and in many other ways, the Institution continues in relation with most of the important scientific establishments and universities in this country and other lands, thus aiding the progress of science and preventing waste. With the consent of the Regents I have tendered to the National Academy of Sciences and the American Association for the Advancement of Science office accommodations in the Smithsonian building, which have been accepted by the officials of both of these important national organizations. The Institution continues its cooperation with the American Historical Association in accordance with the provisions of the act incorporating that society. In general I deem it one of the important functions of the Institution that it should freely place its administrative machinery and opportunities at the service of all the great national learned societies in the hope that the work of all of them will be aided and duplication of labor and waste of energy avoided.

ADMINISTRATION.

In the administration of the Institution the Secretary has the valued aid of experienced officers and a well-trained staff. The Museum is in the immediate charge of Mr. Richard Rathbun, an Assistant Secretary of the Institution, and the Exchange Service, the Library, and the Regional Bureau for the International Catalogue of Scientific Literature are under the supervision of Dr. Cyrus Adler, an Assistant Secretary. Mr. W. H. Holmes is Chief of the Bureau of American Ethnology, Dr. Frank Baker is Superintendent of the National Zoological Park, and Mr. C. G. Abbot is Director of the Astrophysical Observatory.

A system in vogue of conferences between the Secretary and these officers on all subjects pertaining to the different branches has been maintained. The Secretary, as executive officer of the Board of Regents, deems the administration of the parent Institution his first

care, but fully recognizes the importance of the branches supported by the Government, many of which are inherent in the organic act of the Institution, and desires, in cooperation with the Board and the Congress, to administer and develop these important charges of the Institution.

The duties of the Secretary from the date of the death of Mr. Langley up to the end of January, 1907, when I was appointed to that office, were performed with ability and fidelity by Mr. Richard Rathbun, an Assistant Secretary of the Institution, by designation of the Chancellor under authority of the act of May 13, 1894, providing for the appointment of an Acting Secretary.

It is gratifying to report that the current business of the Institution was conducted in a prompt and efficient manner, and that no arrearages in the work of the Government branches under its direction had to be noted in the quarterly statements made to the President and the annual statement made to Congress in accordance with law.

In view, however, of the recent examination by a commission appointed by the President into the business methods of all of the Government Departments, not including the branches under the charge of the Smithsonian Institution, I thought it wise to appoint a committee for the purpose of examining into the business methods of the Institution and its several branches, with a view to suggesting, if found desirable, improvements in the business methods of the Institution and its various branches, and in the transaction of business between them and the Institution.

Mr. H. W. Dorsey, who had been for many years connected with the Institution, was on March 29 appointed chief clerk.

Several amendments affecting the operation of the civil-service law and rules in their bearing on the personnel of the branches of the Government service under the direction of the Smithsonian Institution were promulgated by Executive order during the year. The only change in the rules, however, which affects the branches of the Institution specifically is that announced in the Executive order of April 15, 1907. This provides that the paragraph in the legislative act approved June 22, 1906 (prohibiting the transfer of any employee in the classified service from one Executive Department to another until the employee shall have served for a term of three years in the Department from which transfer is desired), may be waived in proposed transfers to or from the Smithsonian Institution and certain independent bureaus or offices of the Government, when in the judgment of the Civil Service Commission the interests of the service so require.

FINANCES.

The permanent fund of the Institution and the sources from which it was derived are as follows:

Deposited in the Treasury of the United States.

Bequest of Smithson, 1846		$515,169.00
Residuary legacy of Smithson, 1867		26,210.63
Deposit from savings of income, 1867		108,620.37
Bequest of James Hamilton, 1875	$1,000.00	
Accumulated interest on Hamilton fund, 1895	1,000.00	
		2,000.00
Bequest of Simeon Habel, 1880		500.00
Deposit from proceeds of sale of bonds, 1881		51,500.00
Gift of Thomas G. Hodgkins, 1891		200,000.00
Part of residuary legacy of Thomas G. Hodgkins, 1894		8,000.00
Deposit from savings of income, 1903		25,000.00
Residuary legacy of Thomas G. Hodgkins		7,918.69
Total amount of fund in the United States Treasury		944,918.69

Held at the Smithsonian Institution.

Registered and guaranteed bonds of the West Shore Railroad Company (par value), part of legacy of Thomas G. Hodgkins	42,000.00
Total permanent fund	986,918.69

The balance of the residuary legacy of the late Thomas G. Hodgkins, exclusive of accumulated interest, consisted of United States registered 4 per cent bonds of the par value of $7,850 maturing July 1, 1907. These bonds were sold by order of the Board of Regents, and the gross proceeds aggregating $7,918.69 were deposited in the Treasury of the United States to the credit of the permanent fund.

That part of the fund deposited in the Treasury of the United States bears interest at 6 per cent per annum, under the provisions of the act organizing the Institution and an act of Congress approved March 12, 1894. The rate of interest on the West Shore Railroad bonds is 4 per cent per annum.

The income of the Institution during the year, amounting to $64,444.41, was derived as follows: Interest on the permanent fund, $57,900; proceeds from claims in litigation, $1,292.56; interest of Hodgkins residuary fund, $235.50, and miscellaneous sources, $5,016.35; all of which was deposited in the Treasury of the United States to the credit of the current account of the Institution.

With the balance of $10,184.13, on July 1, 1906, the total resources for the fiscal year amounted to $74,628.54. The disbursements, which are given in detail in the annual report of the executive committee, amounted to $49,936.53, leaving a balance of $24,692.01. Of this

amount $100 was advanced for work yet incomplete and $24,592.01 was on deposit in the Treasury of the United States.

The Institution was charged by Congress with the disbursement of the following appropriations for the year ending June 30, 1907:

International Exchanges	$28,800
American Ethnology	40,000
Astrophysical Observatory	14,000
United States National Museum:	
Furniture and fixtures	20,000
Heating and lighting	18,000
Preservation of collections	180,000
Books	2,000
Postage	500
Rent of workshops	4,580
Building repairs	15,000
New building for National Museum	500,000
National Zoological Park	95,000
International Catalogue of Scientific Literature	5,000
Protection and excavation, ruin of Casa Grande, Arizona	3,000
Total	925,880

The estimates forwarded to Congress in behalf of the Government branches of the Institution, and the appropriations based thereon for the fiscal year ending June 30, 1908, are shown in the following table:

	Estimates.	Appropriations.
International exchanges	$32,000	$32,000
American Ethnology	50,000	40,000
Astrophysical Observatory	14,000	13,000
National Museum:		
Furniture and fixtures	20,000	20,000
Heating and lighting	18,000	18,000
Preservation of collections	190,000	190,000
Books	2,000	2,000
Building repairs	15,000	15,000
Rent of workshops	4,580	4,580
Postage	500	500
Sunday and night opening	11,728	.....
New building for National Museum	1,250,000	1,250,000
National Zoological Park:		
National Zoological Park	100,000	95,000
Repairing roadways and walks	15,000	15,000
Readjustment of boundaries	60,000	.....
International Catalogue of Scientific Literature	5,000	5,000
Protection and excavation, ruin of Casa Grande, Arizona	3,000	3,000
Total	1,790,808	1,703,080

EXPLORATIONS AND RESEARCHES.

STUDY OF OLDER SEDIMENTARY ROCKS.

During the past twenty years I have been studying the older sedimentary rocks of the North American Continent from Newfoundland to Alabama on the eastern side and from southeastern California to northern Montana on the western. In the interior, east of the Rocky Mountains, studies were carried on in Texas, South Dakota, Minnesota, and Wisconsin.

Three important sections remained to be examined—one of the Lower Cambrian in western Nevada, one in northern Montana, and another of the lower Paleozoic Rocks of the main range of the Rocky Mountains in the vicinity of the Canadian Pacific Railroad.

The latter was selected for examination during the field season of 1907, and although the work did not begin until after the close of the fiscal year I will here briefly recount some of its results. Early in July, a camp outfit was secured at Field, British Columbia, and work begun on Mount Stephen. Subsequently sections were studied and measured at Castle Mountain, west of Banff, Alberta; at Lake Louise, south of Laggan, Alberta, and on Mount Bosworth on the Continental Divide near Hector, British Columbia.

Upwards of 20,000 feet of strata were carefully examined and measured, and collections of fossils and rocks made from many localities. It was found that the Cambrian section included over 12,000 feet of sandstones, shales, and limestones, and that the three great divisions of the Cambrian—the Lower, Middle, and Upper—were represented in the section of Bow River series and the Castle Mountain group. Characteristic fossils were found in each division.

ALASKAN EXPEDITION.

In continuation of work already satisfactorily begun, the Secretary authorized, in April of the present year, an expedition for the collection of the remains of large extinct vertebrates, particularly mammals, in Alaska. Although fragmentary materials have been secured there from time to time by various exploring parties and mining expeditions, the country is still, to a considerable extent, a virgin field, and the recent great development of the mining industry makes the present time particularly favorable for the work proposed, especially on account of the facilities for transportation thus rendered available.

The expedition has been placed in charge of Mr. C. W. Gilmore, a member of the staff of the National Museum, who will have the services of a guide trained in the methods of the work to be accomplished and thoroughly familiar with the regions to be explored.

The research is an important one and it is hoped by means of it to increase our knowledge of the extinct fauna of the country, and to add valuable and interesting specimens to the collection of the Museum.

FOSSIL FISHES OF BRAZIL.

A moderate grant was approved for the preparation of an illustrated article, to be prepared in collaboration by Dr. David Starr Jordan and Dr. J. C. Branner, on a unique collection of fossil fishes from the Barra do Jardin, a locality near Ceará, Brazil.

About 1834 a collection of these fossil fishes was received by Louis Agassiz, and from it he described seven new species, some of which have never been seen since his time. Some species from the same locality are now in the British Museum, and Stanford University has recently received nodules containing specimens of all those heretofore described and probably several additional ones not before noted. Doctors Jordan and Branner are thus enabled to give information supplementary to any heretofore recorded in regard to this interesting species of fossil fishes. An article describing the research will be submitted to the Institution for publication when completed.

ARIZONA METEORITES.

In April, 1907, Dr. George P. Merrill, head curator of geology in the National Museum, received a limited grant for the purpose of examining the remarkable craterform depression known as Coon Butte, near Canyon Diablo, Arizona, with a view to determining whether it was caused by explosive volcanic action, as assumed by some investigators, or due to the impact of a mass of meteoric iron, as asserted by others. In conducting the research a general survey was made of the amount and distribution of meteoric irons and associated materials of the locality.

Two preliminary papers, one describing a hitherto unrecognized type of meteoric iron, and the other a peculiar form of metamorphism in the siliceous sandstone of the Butte, have been submitted and published in the Proceedings of the National Museum and the Smithsonian Miscellaneous Collections. The entire investigation will be reported on in detail after the results are collated and arranged.

At the conclusion of the work at Coon Butte, Doctor Merrill visited the fossil forest, near Adamana, Ariz., under the authorization of the Department of the Interior, and made collections of the silicified woods for the purpose of supplying the numerous applications received from schools and colleges for such materials.

GEOLOGY OF THE ALPS.

The problem of the structure of the Alps, always a question of intense interest, has been the subject of more than usual attention

and discussion, especially in Europe, during the last five years. The topic being one of vast importance in general geology also, it was decided to make it the subject of special study during the summer of 1907, and Mr. Bailey Willis, a geologist prepared for the work by previous experience and training, was detailed for the purpose, under a grant from the Institution.

It is hoped that this investigation, the results of which will be issued in one of the Smithsonian publications, will aid in solving questions of great importance in general geology.

SEISMOLOGICAL INVESTIGATIONS.

The great earthquake at San Francisco brought prominently to the attention of scientific men and establishments the importance of seismological study, and when on August 16, 1906, the earthquake in Chile took place, it seemed desirable that a competent investigator should be sent to that country to make a study on the spot in order that the disturbance in Chile might be compared with that in California, and utilized for the furtherance of knowledge of this important subject.

Through the courtesy of the Department of State cable communication was had with the American minister in Chile, and it was ascertained that the Government of Chile had appointed a commission consisting of competent astronomers and geologists and that there was no need of sending an observer from the Institution. The American minister in Chile and Mr. Heber D. Curtis, of the Lick Observatory Station, at Santiago, kept the Institution informed as to the progress of the investigation. In general it seems to be determined that there had been some elevation of the coast of Chile and that on the other hand there had been found no traces of a rift such as caused the earthquake at San Francisco. Brief abstracts from the communications received have been published from time to time in the Smithsonian Quarterly.

Meanwhile the importance of seismological investigation, both national and international, has received attention, and plans have been considered for establishing stations in this country, but the Institution is without funds to further the object, and attempts to secure special means or endowment for the purpose have as yet not met with satisfactory results.

In connection with this subject it should be said that the frequent reports of observations of earthquakes at sea which reach the Hydrographic Office of the Navy Department are, through the courtesy of that Department, regularly transmitted to the Institution and are made known to students interested in this subject with the hope that all the data when correlated may prove of advantage in the study of these great destructive phenomena.

AERODROMIC RESEARCHES.

Although the experimental work in aerodromics begun by Secretary Langley is not now being carried on at the Institution, it can not but be gratifying to note the fact that this subject, which was placed upon a solid foundation by the research work of Mr. Langley, is more and more engaging the attention of physicists and engineers, military establishments, and students throughout the world, and that the impetus given to it by my predecessor is everywhere recognized. This Institution has by no means abandoned its interest in the subject, and the collection of books and pamphlets brought together here is maintained as a separate collection and rendered accessible to students. I have made a special grant to Mr. C. M. Manly, who was associated with Mr. Langley in this work, for the completion of a memoir bringing the experiments up to 1905, and another for the preparation of a bibliography on the subject, which it is hoped may be useful to students.

Dr. Alexander Graham Bell, a Regent of the Institution, and a distinguished student of many natural problems, is engaged upon aerodromic experiments which it is expected will prove useful and important. He and others have used, it is hoped with profit, the material in the collections gathered here. The prominence of the Institution in this subject has made the National Museum the natural place of deposit for the original types of different forms of flying machines, and there is no doubt but that the most important types of models of the early attempts to solve this great subject will be found in the collections here.

The engine of the large aerodrome was displayed in New York at the exhibition of the Aero Club in December, 1906.

INVESTIGATIONS UNDER THE HODGKINS FUND.

STUDY OF ATMOSPHERIC AIR IN RELATION TO MANKIND.

Investigations on subjects of general hygienic interest, such as have been promoted since the beginning of the administration of the Hodgkins fund, continue to receive encouragement. Publications are issued in this connection, and communications addressed to the Institution on subjects which the fund may properly aid, do not fail to receive attention. The Hodgkins gold medal, which is bestowed for important contributions to our knowledge of the nature and properties of atmospheric air, or for practical applications of our existing knowledge of them to the welfare of mankind, is a testimonial not only to the wishes of the founder of the fund, but also an expression of the interest of the Institution in this regard.

Among other topics, the question of the effective ventilation of buildings has been given attention, and initiative steps have been taken to learn what investigators are making a serious study of this important subject. The vitiation of the exterior atmosphere in closely settled localities is also recognized as a question of great importance to the dwellers in cities, and an effort is making through the publications of the Hodgkins fund to disseminate the results of late noteworthy investigations in this connection.

The application of atmospheric air to therapeutics has received consideration, and while no research having for its object the direct use of the atmosphere as a curative agent has, as yet, been aided, the work furthered by the fund, excepting that which deals almost exclusively with the mechanics of the atmosphere, is closely related to medicine and hygiene. Consequently the reports of investigations and experiments prosecuted in widely separated localities, such as London, South Africa, Paris, and the cities of our own country, have been followed with interest, in common with all classes of research which make broader the way for the practical utilization of our knowledge of the nature and properties of atmospheric air for the welfare of mankind.

ABSOLUTE MEASURE OF SOUND.

The research of Dr. A. G. Webster, of Clark University, on the absolute measure of sound, which was aided again during the present year by a moderate grant from the Hodgkins fund, is reported as advancing satisfactorily toward completion. The instruments prepared especially for use in this research are expected to prove of service in solving many practical questions relating to sound, such, for instance, as the testing of sound-proofing materials, or of audible signals. In conducting the investigation many delicate points in the theory of such instruments have been settled by actual experiment, so that, in some particulars, the experimental knowledge is in advance of the present mathematical theory.

The manuscript describing the methods and results of this research will be submitted to the Institution for publication when completed.

PROPERTIES OF MATTER AT VERY LOW TEMPERATURES.

The investigation of the properties of matter at very low temperatures, involving the use of liquid air, in aid of which a grant was approved in 1906, from the Hodgkins fund of the Institution on behalf of Prof. E. L. Nichols, of Cornell University, has been steadily progressing. The research is now to enter on a careful study of the index of the refraction of gases, and gaseous mixtures and vapors, over extreme ranges of pressure of temperature. The effect on the

physical properties of carbon of the remarkable absorption of gases at low temperatures is to be investigated, and two methods of determining the specific heat of gases have been perfected. The investigation of the properties of matter at the temperature of liquid hydrogen will also be continued and the results recorded.

STUDY OF THE UPPER ATMOSPHERE.

The meteorological experiments of Mr. A. Lawrence Rotch with registering balloons, conducted from St. Louis as the starting point, have been again aided by a grant from the Hodgkins fund. Before the close of similar experiments by Mr. Rotch from the same point in 1906, the extreme height of nearly 10 miles was attained, and a temperature of —76° F. was once recorded somewhat below 7 miles.

This final series of ascensions aided by the Institution is intended to supply data for the season of the year in which observations of the upper air have heretofore been the least frequent, and it is hoped that the endeavor to ascertain the annual variation of temperature at great heights in the free air above the American continent will thus be materially furthered.

A summary of the results of the meteorological research conducted by Mr. S. P. Fergusson, mentioned in the previous Report as having been aided by a moderate grant from the Hodgkins fund of the Institution, has been submitted.

Stations for these experiments were established on the summit of Mount Washington, 1,916 meters above sea level, and at Twin Mountain, 1,500 meters lower and 15 miles distant. Louvred shelters were built for the proper exposure and protection of the instruments at these stations, and the anemometer was erected on the old Tip Top House, the highest point on the summit of Mount Washington. Records were made at the stations, as nearly as possible continuous, of pressure, temperature, humidity, and wind velocity, while the meteorographs recording the same elements were sustained by kites in the free air for as long a time as possible during the research. Observations of the formation of clouds on the mountain and in the free air were also made.

While the apparatus used in this research was the same in principle as that heretofore employed, it is hoped that certain devices which were suggested by the conditions, and successfully adopted, will prove advantageous in later experiments. The time available for this research was necessarily limited, but the kites on several different occasions carried the meteorograph sufficiently high for comparison with the records obtained on Mount Washington. On the 6th of September the instrument was kept at approximately the same height in the free air and on the summit of Mount Washington for eight hours between noon and 10 o'clock p. m.

In view of the short time, practically about three weeks, during which the climatic conditions rendered it possible to prosecute this research, its results as reported by Mr. Fergusson may be considered satisfactory.

MECHANICS OF THE EARTH'S ATMOSPHERE.

There was published by the Institution several years ago a volume, entitled "Mechanics of the Earth's Atmosphere," which consisted of translations of articles by various eminent meteorologists. Arrangements have been made with Prof. Cleveland Abbe, editor of the first volume, for the preparation of a second volume on the same topic.

THE ORGANS OF FLIGHT.

An additional grant has been approved this year on behalf of Dr. R. von Lendenfeld, of the University of Prague, for an investigation of the organs of flight of the best representative flyers of the insect orders—Lepidoptera, Hymenoptera, and Diptera. A detailed account of this research will be submitted on its conclusion for publication by the Institution if desired.

Previous researches of Doctor von Lendenfeld have been described in articles prepared under his supervision by Drs. Leo Walter and Bruno Müller. Doctor Walter's article, already published, was referred to in the previous report. The paper by Doctor Müller on the air sacs of the pigeon is now in course of publication.

SMITHSONIAN TABLE AT NAPLES ZOOLOGICAL STATION.

In July, 1906, the renewal of the lease of the Smithsonian table in the Naples Zoological Station for a term of three years from January 1, 1907, was decided on, and the director so informed. Doctor Dorhn, with his usual ready courtesy, at once notified the Institution of his willingness to arrange for a double occupancy by extending the time of an appointee then conducting an important research at Naples, although the seat had already been assigned for the period in question to another investigator.

It is the intention of the Institution to interfere in no way with the regular assignment of the table, and the desire of the Director to maintain the international character of the station by encouraging the action of the various countries in supporting individual tables is fully appreciated. Nations widely separated, at least geographically, meet there on the common ground of interest in science, and thus, as an appointee of the Smithsonian seat expressed in his report to the Institution, an international peace congress, the importance of which can not be overestimated, is always in session at the Naples Zoological Station.

Several appointments to the Smithsonian table at Naples were ratified for the period between June 30, 1906, and June 30, 1907, the entire occupation of the seat for the year being eleven months. Since inquiries as to available dates are frequently received a year or even two years in advance of the time desired, it may be well to repeat that in the interest of all applicants it is not customary to approve a request for the seat more than six months in advance of the period desired.

By extension of his appointment, Dr. Stewart Paton, of Johns Hopkins University, occupied the Smithsonian seat until the end of June, 1906. His work at Naples dealt principally with the problems hitherto unsolved in connection with the nervous system and its relations to the action of the heart. As before noted, the results of this interesting research will be published on completion.

The occupation of the Smithsonian seat at Naples by Dr. Maynard M. Metcalf, formerly of the Woman's College in Baltimore, and now of Oberlin College, began before the close of the final session of Doctor Paton. Doctor Metcalf reports that on beginning his term at the station he continued his study of the parasites of frogs prosecuted at Würzburg and designed for publication in connection with work done there.

There being apparently some doubt as to whether or not the advantages of the Smithsonian seat at Naples are available to hitherto unknown investigators, it may be well to state again that the application of any student, who is suitably recommended to the Institution as prepared to undertake original work in embryological, histological, or other fields, will not fail to receive prompt consideration.

The continued prompt and helpful action of the advisory committee in reporting on questions relating to appointments, etc., is appreciated. I am glad to say that the personnel of the committee remains the same as mentioned in the report of last year.

PUBLICATIONS.

It is mainly through its publications that that vital principle of the Institution, "the diffusion of knowledge among men," is carried out. The Institution proper maintains three regular series of publications, the Smithsonian Contributions to Knowledge, the Smithsonian Miscellaneous Collections, and the Annual Reports, while under its auspices are issued the Annual Reports, Proceedings, and Bulletins of the National Museum, the Reports and Bulletins of the Bureau of American Ethnology, and the Annals of the Astrophysical Observatory, the whole presenting a fund of information covering a wide range of human knowledge in both a specialized and general form.

The Smithsonian Contributions to Knowledge, now in their thirty-fifth volume, are restricted to the publication of positive additions to human knowledge resting on original research, all unverified speculation being rejected. The Smithsonian Miscellaneous Collections are designed to contain reports on the present state of our knowledge in particular branches of science, instructions for collecting and digesting facts and materials for research, lists and synopses of species of the organic and inorganic world, reports of explorations, and aids to bibliographical investigations. This series is now in its fiftieth volume, and in the quarterly issue provision has been made for the early publication of short papers descriptive of new discoveries or containing information of current interest in all departments of science.

In the Smithsonian Contributions to Knowledge several important works are in press. One of these is a memoir on "Glaciers of the Canadian Rockies and Selkirks," by Dr. William H. Sherzer, of the Michigan State Normal College, which is a final report on the Smithsonian expedition of 1904. A preliminary report on this expedition was published in the quarterly issue of the Smthsonian Miscellaneous Collections in 1905. There is also a work by Prof. E. A. Andrews, of Johns Hopkins University, on "The young of the crayfishes astacus and cambarus," giving the results of long and careful observation of the growth of these common animals.

Prof. Hubert Lyman Clark, of the Museum of Comparative Zoology at Cambridge, Mass., who has been at work for some time classifying and describing the specimens of Apodous Holothurians, or sea cucumbers, in the National Museum—a collection numbering over a thousand specimens from the shores of North and South America—has submitted a report embracing the result of his study on the families Synaptidæ and Molpadiidæ which will appear some time during the next year. Other memoirs for the series of Contributions are in preparation.

The quarterly issue of the Smithsonian Miscellaneous Collections, which was temporarily suspended in 1905, was resumed in September, 1906. Since then parts 3 and 4 of Volume III, and part 1 of Volume IV, have been completed. Among the recent papers published in this series is a "Letter of Dr. Diego Alvarez Chanca," dated 1494, relating to the second voyage of Columbus to America, which was translated and annotated by Dr. Fernandez de Ybarra. This letter is notable as being the first "written document of the natural history, ethnography, and ethnology of America."

In the regular series of Smithsonian Miscellaneous Collections there has been completed a second paper on the "Attainment of very low temperatures" dealing with the "self-intensive process of liquefy-

ing gases." This paper is a report on researches carried on under a Hodgkins grant by Dr. Morris W. Travers, of the University College, Bristol, England.

Two other papers are very nearly completed. One is a "Report on the Crustacea of the North Pacific Exploring Expedition of 1853–1856," by the late Dr. William Stimpson. This manuscript has been in hand since 1872, but for various reasons could not heretofore be published. The whole work was carefully gone over by Miss Mary J. Rathbun, Assistant Curator of Marine Invertebrates in the National Museum, who says in her preface:

> The . . . report has been treated as an historical document, and is published substantially as it was written by the author, the only additions being the references to his preliminary descriptions, and the footnotes giving the current or accepted name where it differs from that used by Doctor Stimpson. It is hoped that the value of the descriptions will more than compensate for the antiquated nomenclature . . . there are very few students who have not felt the need of more light on those rare genera and species known only from brief Latin diagnoses.

Another publication is a "Catalogue of Earthquakes on the Pacific Coast from 1897 to 1906," compiled by Mr. Alexander G. McAdie, as a supplement to the list of earthquakes from 1769 to 1896, compiled by Dr. E. S. Holden, and published in the Smithsonian Miscellaneous Collections in 1898.

A new edition of the Smithsonian Meteorological Tables to meet the continued demand for this work is in press. The plates have been considerably revised by Prof. Cleveland Abbe to meet present requirements.

The Annual Report of the Board of Regents to Congress, which is printed at the Government Printing Office, has been the chief medium through which the Institution has been enabled to disseminate scientific information to the world at large. Besides the official account of the operations of the Institution, this report has for over half a century included a general appendix giving a record of the progress in different branches of knowledge, compiled largely from journals in foreign languages and the transactions of scientific and learned societies throughout the world. The considerable number of copies of this publication placed by Congress at the disposal of the Institution has rendered possible a wide distribution to important libraries and institutions of learning, but the allotment is wholly insufficient to supply more than a small fraction of the individual requests, and the popular demand for the volume has so constantly increased that the entire edition of each year's report is exhausted within a few months of its appearance.

The Institution proper distributed during the year a total of 32,921 volumes and separates of Smithsonian Contributions to Knowl-

edge, Miscellaneous Collections, Annual Reports, publications not included in the regular series, and publications not Smithsonian.[a]

The Proceedings of the United States National Museum, the first volume of which was issued in 1878, are intended as a medium for the publication of original papers based on the collections of the Museum, setting forth newly acquired facts in biology, anthropology, and geology, or containing descriptions of new forms and revisions of limited groups. A volume is issued annually or oftener for distribution to libraries and scientific establishments, and in view of the importance of the more prompt dissemination of new facts a limited edition of each paper is printed in pamphlet form in advance. The dates at which these separate papers are published are recorded in the table of contents of the volume. The Museum Bulletin, publication of which was begun in 1875, comprises a series of more elaborate papers issued separately, and, like the Proceedings, is based chiefly, if not wholly, on the collections of the Museum. A quarto form of the Bulletin, known as the "Special Bulletin," has been adopted in a few instances in which a larger size of page was deemed indispensable. Since 1902 the volumes of the series known as "Contributions from the National Herbarium," and containing papers relating to the botanical collections of the Museum, have been published in the Bulletin series.

The Annual Report of the Museum is printed as a separate volume of the report of the Board of Regents to Congress.

The publications of the Bureau of American Ethnology, consisting of annual reports and bulletins, relate to the operations of the Bureau in its various branches of exploration and research. Part I of the Handbook of American Indians (A to M) was issued in March and the main portion of Part II is in type. The Twenty-fourth Annual Report has been published and much progress made on the Twenty-fifth Report. Several Bulletins have been issued.

The Annual Report of the American Historical Association for the year 1905 was transmitted to Congress in May, 1906, under the requirements of the act of incorporation of the association, but only one of the two volumes had been completed at the close of the fiscal year. The Smithsonian Institution is by law allowed a number of copies of reports of this association, which are distributed in exchange for the publications of various foreign and American historical societies.

There was also forwarded to Congress on February 25, 1907, the ninth report of the National Society of the Daughters of the American Revolution, in accordance with the act of incorporation of that organization.

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[a] Contributions to Knowledge, 775; Miscellaneous Collections, 10,059; Reports, 18,[illegible]; publications not in regular series, 2,890; publications not Smithsonian,

In accordance with the act of Congress approved March 30, 1906, providing that the cost of printing and binding for the Executive Departments and Government bureaus shall be charged to specific appropriations for the Departments and bureaus, and the further provision in the sundry civil act of June 30, 1906, that no appropriations except those specifically for printing and binding shall be used for such purpose, special allotments have been made to the Institution and its branches for the year ending June 30, 1908, as follows:

For the Smithsonian Institution for printing and binding annual reports of the Board of Regents, with general appendixes	$10,000
For the annual reports of the National Museum, with general appendixes, and for printing labels and blanks, and for the bulletins and proceedings of the National Museum, the editions of which shall not exceed 4,000 copies, and binding, in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library	33,000
For the annual report and bulletins of the Bureau of American Ethnology	21,000
For miscellaneous printing and binding:	
International exchanges	200
International Catalogue of Scientific Literature	100
National Zoological Park	200
Astrophysical Observatory (including the publishing of results of researches, not exceeding 1,500 copies)	2,000
Annual report of the American Historical Association	7,000
Total	73,500

The allotments to the Institution and its branches under the head of public printing and binding during the past fiscal year were as far as practicable expended prior to June 30. It was, however, difficult to determine the actual balances available at any particular date, for the reason that the actual cost of publications in press could not be ascertained until their completion. The estimates not being accurate enough to serve as a basis for calculation, the transmission of new works was in some cases delayed so long that their completion was impracticable before the appropriation had expired. In the case of the allotment of $10,000 for the Smithsonian Reports it was thus possible to expend only $8,127.98; of $21,000 allotted to the Bureau of American Ethnology, $19,831.76 was expended, and of the $39,000 allotted for the National Museum and the American Historical Association there was expended $38,980.47.

ADVISORY COMMITTEE ON PRINTING AND PUBLICATION.

The advisory committee on printing and publication appointed by the Acting Secretary on February 7, 1906, in order that the practice of the Institution in the supervision of its publications might correspond with that of the Executive Departments as prescribed in the

President's order of January 24, 1906, held twenty-six meetings during the year and reported on one hundred and one manuscripts submitted for publication, besides numerous blank forms for use in the bureaus of the Institution.

Dr. Leonhard Stejneger, of the National Museum, has been added to the committee, which consists of the following members: Dr. Cyrus Adler, Assistant Secretary, chairman; Dr. F. W. True, of the United States National Museum; Mr. F. W. Hodge, of the Bureau of American Ethnology; Dr. Frank Baker, of the National Zoological Park; Mr. C. G. Abbot, of the Astrophysical Observatory; Mr. W. I. Adams, of the International Exchanges; Mr. A. Howard Clark, of the Smithsonian Institution, and Dr. Leonhard Stejneger, of the United States National Museum.

The printing committee has had under consideration the advantage of a uniform system of abbreviation of works cited by naturalists in their publications. A preliminary list of abbreviations has been prepared for the criticism of the scientific staff of the Institution and its branches.

Dating of publications.—Among the questions considered by the printing committee was the dating of publications, particularly such papers as contain descriptions of new genera or species in natural history, and upon the recommendation of the committee the Institution has adopted the rule that "whenever fifty copies of any paper shall have been mailed or distributed by messenger, the paper shall be regarded as having been published, it being understood that the date of such mailing or distribution shall coincide with the date of record in the Smithsonian document rooms and with the date printed upon the publication."

Durable book paper.—The introduction of a very large portion of wood pulp and ground wood in book paper to the exclusion of cotton or linen rags formerly used in its manufacture has been found greatly to decrease the durability of modern publications. The printing committee, after considering this problem, concluded that paper hereafter used in Smithsonian publications should be composed of not less than 50 per cent of rag stock and be free from injurious chemicals. Definite specifications as to the composition of paper will later be formulated, in cooperation with the Executive Departments.

THE LIBRARY.

The total accessions during the year to the Smithsonian library aggregate 14,582 volumes and parts. The major part of these was placed in the Smithsonian deposit in the Library of Congress, which now contains the libraries of the Secretary's office, the National Museum, the Astrophysical Observatory, and the National

Zoological Park. There were also numerous additions to the library of the Bureau of American Ethnology, which is separately administered. It is estimated that the equivalent of 11,000 volumes were transmitted to the Library of Congress besides public documents and other gifts to that Library transmitted through the International Exchange service, and such public documents as were presented to the Institution and sent direct to the Library. Two hundred and fifty new periodicals were added to the receipts and some 600 defective series were partially or entirely filled up. The work of the International Catalogue has brought a considerable number of authors' separates to the Library. Efforts have been made to increase the series of address books in the office of the International Exchanges service. The estate of S. P. Langley turned over to the Institution his scientific library, which has been divided up among the various divisions. The Gen. Watts de Peyster library of Napoleon and other subjects was increased about 288 volumes. It is with regret that I record the death of General de Peyster, who was a well-known collector and had been for many years a generous donor to the Institution.

The quarters of the library both in the Institution and Museum are entirely inadequate, and no relief seems possible until the completion of the new building for the National Museum, when it is hoped that a large part of the main floor of the Smithsonian building can be devoted to library purposes, forming a central library for the Institution and all its branches, though of course the sectional library system will be continued as heretofore.

PRESERVATION OF ARCHEOLOGICAL SITES.

The Institution has for many years taken a deep interest in preserving archeological objects on the public domain from vandals and relic hunters and making them accessible under proper regulations to scientific institutions and colleges. A law covering this subject was approved on June 8, 1906. Under the terms of this act uniform regulations for its administration were to be prepared by the Secretaries of the Interior, War, and Agriculture. At the request of the Departments, the Institution participated in several conferences of representatives of the three Departments looking to the preparation of such rules, which were promulgated on December 28, 1906. A little later some dissatisfaction was expressed with these regulations by archeologists, and at their request I invited the three Departments to reconsider the regulations. Accordingly, further conferences were held by representatives of the Departments, of the Institution, and of the Archeological Institute of America, resulting in the understand-

ing that the present regulations should have a reasonable trial before any amendment be considered. The regulations are as follows:

UNIFORM RULES AND REGULATIONS PRESCRIBED BY THE SECRETARIES OF THE INTERIOR, AGRICULTURE, AND WAR TO CARRY OUT THE PROVISIONS OF THE "ACT FOR THE PRESERVATION OF AMERICAN ANTIQUITIES," APPROVED JUNE 8, 1906 (34 STAT. L., 225.)

1. Jurisdiction over ruins, archeological sites, historic and prehistoric monuments and structures, objects of antiquity, historic landmarks, and other objects of historic or scientific interest, shall be exercised under the act by the respective Departments as follows:

By the Secretary of Agriculture over lands within the exterior limits of forest reserves, by the Secretary of War over lands within the exterior limits of military reservations, by the Secretary of the Interior over all other lands owned or controlled by the Government of the United States, provided the Secretaries of War and Agriculture may by agreement cooperate with the Secretary of the Interior in the supervision of such monuments and objects covered by the act of June 8, 1906, as may be located on lands near or adjacent to forest reserves and military reservations, respectively.

2. No permit for the removal of any ancient monument or structure which can be permanently preserved under the control of the United States *in situ*, and remain an object of interest, shall be granted.

3. Permits for the examination of ruins, the excavation of archeological sites, and the gathering of objects of antiquity will be granted, by the respective Secretaries having jurisdiction, to reputable museums, universities, colleges, or other recognized scientific or educational institutions, or to their duly authorized agents.

4. No exclusive permits shall be granted for a larger area than the applicant can reasonably be expected to explore fully and systematically within the time limit named in the permit.

5. Each application for a permit should be filed with the Secretary having jurisdiction, and must be accompanied by a definite outline of the proposed work, indicating the name of the institution making the request, the date proposed for beginning the field work, the length of time proposed to be devoted to it, and the person who will have immediate charge of the work. The application must also contain an exact statement of the character of the work, whether examination, excavation, or gathering, and the public museum in which the collections made under the permit are to be permanently preserved. The application must be accompanied by a sketch plan or description of the particular site or area to be examined, excavated, or searched, so definite that it can be located on the map with reasonable accuracy.

6. No permit will be granted for a period of more than three years, but if the work has been diligently prosecuted under the permit, the time may be extended for proper cause upon application.

7. Failure to begin work under a permit within six months after it is granted, or failure to diligently prosecute such work after it has been begun, shall make the permit void without any order or proceeding by the Secretary having jurisdiction.

8. Applications for permits shall be referred to the Smithsonian Institution for recommendation.

9. Every permit shall be in writing and copies shall be transmitted to the Smithsonian Institution and the field officer in charge of the land involved. The permittee will be furnished with a copy of these rules and regulations.

10. At the close of each season's field work the permittee shall report in duplicate to the Smithsonian Institution, in such form as its Secretary may prescribe, and shall prepare in duplicate a catalogue of the collections and of the photographs made during the season, indicating therein such material, if any, as may be available for exchange.

11. Institutions and persons receiving permits for excavation shall, after the completion of the work, restore the lands upon which they have worked to their customary condition, to the satisfaction of the field officer in charge.

12. All permits shall be terminable at the discretion of the Secretary having jurisdiction.

13. The field officer in charge of land owned or controlled by the Government of the United States shall, from time to time, inquire and report as to the existence, on or near such lands, of ruins and archeological sites, historic or prehistoric ruins or monuments, objects of antiquity, historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest.

14. The field officer in charge may at all times examine the permit of any person or institution claiming privileges granted in accordance with the act and these rules and regulations, and may fully examine all work done under such permit.

15. All persons duly authorized by the Secretaries of Agriculture, War, and Interior may apprehend or cause to be arrested, as provided in the act of February 6, 1905 (33 Stat. L., 700), any person or persons who appropriate, excavate, injure, or destroy any historic or prehistoric ruin or monument, or any object of antiquity on lands under the supervision of the Secretaries of Agriculture, War, and Interior, respectively.

16. Any object of antiquity taken, or collection made, on lands owned or controlled by the United States, without a permit, as prescribed by the act and these rules and regulations, or there taken or made, contrary to the terms of the permit, or contrary to the act and these rules and regulations, may be seized wherever found and at any time, by the proper field officer or by any person duly authorized by the Secretary having jurisdiction, and disposed of as the Secretary shall determine, by deposit in the proper national depository or otherwise.

17. Every collection made under the authority of the act and of these rules and regulations shall be preserved in the public museum designated in the permit and shall be accessible to the public. No such collection shall be removed from such public museum without the written authority of the Secretary of the Smithsonian Institution, and then only to another public museum, where it shall be accessible to the public; and when any public museum, which is a depository of any collection made under the provisions of the act and these rules and regulations, shall cease to exist, every such collection in such

public museum shall thereupon revert to the national collections and be placed in the proper national depository.

WASHINGTON, D. C., *December 28, 1906.*

The foregoing rules and regulations are hereby approved in triplicate and, under authority conferred by law on the Secretaries of the Interior, Agriculture, and War, are hereby made and established, to take effect immediately.

E. A. HITCHCOCK,
Secretary of the Interior.
JAMES WILSON,
Secretary of Agriculture.
WM. H. TAFT,
Secretary of War.

The Institution has promptly acted upon all requests for advice, either through the Bureau of Ethnology when archeological sites were concerned or through the National Museum when paleontological collections were desired.

The national domain possesses priceless treasures for the archeologist and for the public generally, and this regulation of excavation is in the interest not only of science but of the whole people.

CASA GRANDE RUIN IN ARIZONA.

As was stated in the previous report, Congress appropriated $3,000, to be expended under the supervision of the Secretary, for the protection of the Casa Grande ruin, in Pinal County, near Florence, Ariz., and for excavation on the reservation. This work was placed in the immediate charge of Dr. J. Walter Fewkes, of the Bureau of American Ethnology, an experienced archeologist, and the results reached have been beyond expectations entertained. All the mounds on the reservation have been opened and about three-fifths of the compound excavated. In the course of the work there was found a wall which not only surrounds Casa Grande but also 43 large rooms. The newly discovered walls have been repaired and protected, and when completed there will be restored for posterity a representative prehistoric settlement of the desert of southern Arizona.

A preliminary report of the first year's work has been prepared, and since the close of the fiscal year has appeared in the Smithsonian Miscellaneous Collections. Congress granted a second appropriation to complete the work, which will, as in the previous year, be carried on under the direction of Doctor Fewkes. The very interesting collections which have incidentally been found have been deposited in the National Museum.

The appropriation for the protection and excavation at Casa
was made two years ago at the recommendation of the
ıent of the Interior, but the work was placed under the

direction of the Institution at the initiative of the Committee on Appropriations, without any suggestion from the Institution itself. The plans for the work were submitted to the authorities of the Interior Department and approved by it, and a synoptic report of the year's operations was transmitted to the Secretary of the Interior.

CORRESPONDENCE.

The correspondence of the Institution shows that there is even in the more remote parts of this country and abroad, a widespread knowledge that one of the primary purposes of the Smithsonian Institution is the diffusion of knowledge, although the public at large does not always possess a very definite idea of the exact scope of the Institution's functions. Hence there are received annually hundreds of letters asking for information covering practically every field of science, from a simple inquiry concerning the identity of some natural-history specimen to a request for an explanation of some problem in astronomy or physics, which may require quite exhaustive study on the part of a member of the staff. All legitimate requests for scientific information are cheerfully responded to as far as practicable, and by this means much useful knowledge is disseminated, although the preparation of these communications consumes a considerable part of the time of both the scientific and clerical staff. It may be well to state in this connection, however, that the Institution does not undertake to maintain a "question bureau," such as is frequently conducted by newspapers and magazines, nor does it furnish information of a commercial nature, which could as readily be obtained from a professional advisor upon the payment of a fee.

In addition to this general correspondence, there is carried on by the several branches of the Institution—the National Museum, the Bureau of American Ethnology, the National Zoological Park, the International Exchanges, and the Astrophysical Observatory—a considerable correspondence relating to the respective activities of each. All matters affecting questions of policy, and all appointments, however, receive the personal consideration of the Secretary.

The practice of press-copying outgoing letters in books has been abandoned during the year, and the use of carbon copies substituted in its stead. Other changes have also been instituted in the method of filing, by which the papers on any given subject are made more readily accessible for reference.

EXPOSITIONS, CONGRESSES, AND CELEBRATIONS.

Jamestown Exposition.—Out of an appropriation of $200,000 for the Government display at the Jamestown Exposition, $16,000 was allowed for the preparation of exhibits by the Smithsonian Institu-

tion and the National Museum, and a separate building—Annex B—about 60 by 100 feet, was provided for the installation and care of the exhibit. Mr. W. de C. Ravenel, administrative assistant of the United States National Museum, represented the Smithsonian Institution and the National Museum on the Government board, and was assisted in the preparation of the exhibits by an advisory committee consisting of Dr. Cyrus Adler, Assistant Secretary of the Smithsonian Institution; Mr. W. H. Holmes, chief of the Bureau of American Ethnology; and Mr. A. Howard Clark, Curator of History, United States National Museum. The exhibit is entirely historical in character and mainly has to do with the development of the United States along various lines, such as in land transportation, firearms, photography, medicine, and other branches.

Bordeaux Exposition.—The United States exhibit at the International Maritime Exposition, opened at Bordeaux, France, May 1, 1907, was collected and installed by the Smithsonian Institution at the request of the Department of State. Mr. Ravenel, administrative assistant of the United States National Museum, was designated by the Secretary to prepare and install this exhibit.

Congress of Americanists.—The fifteenth annual Congress of Americanists was held in Quebec September 10–15, 1906. Mr. W. H. Holmes, chief of the Bureau of American Ethnology, was unable to accept the designation of delegate which was tendered to him, but his place was filled by Dr. Walter Hough, of the Division of Anthropology in the National Museum, who represented the Smithsonian Institution, the National Museum, and the Bureau of American Ethnology.

International Geological Congress.—The Tenth International Geological Congress was held in the City of Mexico September 6–14, 1906. Prof. S. F. Emmons, of the United States Geological Survey, acted as representative for the Smithsonian Institution.

Linnæus celebrations.—The two hundredth anniversary of the birthday of Linné was celebrated at New York May 4, 1907, by the New York Academy of Sciences. Dr. Theodore Gill represented the Smithsonian Institution on that occasion. Professor Farlow, of Harvard University, represented the Institution at the Linnæus celebration of the Royal Swedish Academy of Sciences at Upsala on May 25.

Dedication of engineering building.—Mr. George C. Maynard, of the National Museum, represented the Smithsonian Institution at the dedication of the new building for the engineering department of the University of Pennsylvania, September 26, 1906.

Memorial to Louis Agassiz.—At the unveiling of the memorial to Louis Agassiz, in the Hall of Fame at Columbia University, New York, on May 30, 1907, the Secretary of the Smithsonian Institution

presented a brief tribute to that great man of science which was afterwards published in the Smithsonian Miscellaneous Collections.

Aberdeen anniversary, etc.—Prof. F. W. Clarke represented the Institution on the occasion of the four hundredth anniversary of the Aberdeen University, October 20, 1906. At the request of the Department of State, the Institution recommended as delegates of the Government to the International Zoological Congress, to be held in Boston in August, 1907, Mr. Richard Rathbun, Dr. Theodore Gill, Dr. W. H. Dall, Dr. F. W. True, Mr. Leonhard Stejneger, and Dr. Harrison G. Dyar. The Secretary attended the inauguration of the Carnegie Institute at Pittsburg, April 11–13, 1907. Mr. Arnold Hague was appointed to represent the Institution at the centenary of the Geological Society of London, to take place September 19, 1907, and Prof. Simon Newcomb has accepted the designation to represent the Institution at the Fourth International Congress of Mathematicians, to be held at Rome April 6–11, 1908.

Prize essay on fisheries.—In response to an invitation from the International Fishery Congress, the fourth session of which is to be held in Washington in September, 1908, an allotment of $200 has been made from the Smithsonian fund as a prize for the best article on the international regulation of the fisheries of the high seas, their history, objects and results. It is announced that any person, association, or company may compete for the various prizes to be awarded in connection with this congress by complying with the published conditions which govern the competition, as issued from the office of the general secretary of the congress, Dr. H. M. Smith, of the United States Bureau of Fisheries, Washington, D. C.

MISCELLANEOUS.

Improvement and maintenance of Smithsonian grounds.—The sundry civil act approved March 4, 1907, contained an appropriation of $3,000 for the improvement, care, and maintenance of the Smithsonian grounds, and also an appropriation of $5,000 for resurfacing the asphalt roadways in the grounds.

California Academy of Sciences.—As stated in the previous report, the good offices of the Institution were tendered and accepted by the California Academy of Sciences for the purpose of aiding it in replacing its library and collection destroyed by the earthquake and fire of April, 1906. In the report of the Bureau of International Exchanges it is noted that upward of 7,000 valuable publications were secured abroad and forwarded to the academy, and not all of the correspondents of the academy have yet responded to the circular. The Institution also forwarded without cost to the academy very considerable collections of books from individuals and institutions in the

United States, as well as collections of specimens. The academy has expressed its grateful appreciation of the generous attitude of foreign and American societies and of the aid offered by the International Exchange Service of the Smithsonian Institution in rehabilitating its library and collections.

NATIONAL MUSEUM.

The overcrowding of the present Museum building has necessarily continued, so that in many places it presents almost the aspect of a storehouse. Nevertheless, the collections can be viewed by visitors, although not to the advantage which a freer installation would render possible. Meanwhile the roof of the present building is being repaired and various exhibition halls have been isolated with a view to obtaining greater fire protection. Exclusive of the subject of the fine arts, the additions to the Museum during the year consisted of about a quarter of a million specimens representing all the subjects embraced in the Museum collections. Several expeditions for collecting and observation were made by members of the staff. Many of the collections were reclassified and numerous papers published. Of duplicate specimens separated from the collections about 16,000 were distributed in 208 sets to educational establishments in different parts of the United States. The principal labor of representing the Institution and the Museum at the Jamestown Exposition, and the Government, the Institution, and the Museum at the Bordeaux Exposition, fell upon the staff of the Museum. Mr. W. de C. Ravenel, the administrative assistant of the Museum, acted as representative of the Institution for both these expositions with great ability and success.

NEW BUILDING FOR THE NATIONAL MUSEUM.

Although the new building for the National Museum has not progressed so rapidly as had been expected, due almost exclusively to delays in the delivery of the granite, these conditions have now been overcome, and it is confidently expected that the building will be under roof by the spring of 1908 and be ready for occupancy by the beginning of 1909, consuming a period of time not excessive in view of the great size of the building and of the solid and monumental character of its construction.

As the new building approaches completion certain questions connected with the future administration of the Museum necessarily press for consideration. It has been reasonably well determined that the new building will be devoted to the scientific and historical collections, and the present Museum building will be employed for the development of the department of arts and industries; that the upper exhibition hall of the Smithsonian building will be utilized to the

fine-art collection and the lower hall to a library, but carrying with it certain exposition series, such as are appropriate to a library. The appropriation for the construction of the new building did not provide for its equipment, and to commence this work I have included in the estimates to Congress a request for $200,000 to begin the construction of cases and furnishings for the new building.

The purpose of the Museum is, and must continue to be, the custody of the national collections, by which is meant the preservation, classification and exhibition, and work incident thereto. The main purpose of the Museum must never be lost sight of. It is but natural and proper that in the course of classification and arrangement skilled scientific men engaged in this work should make discoveries of importance to science and that the Museum should publish them. In this way the Museum, in all the departments which its collections represent, is a great research institution as well, but this research work is a by-product rather than the fundamental purpose of the Museum. Happily enough, the relationship of the Museum to the Institution is of such a nature that there is no waste of energy, and researches which may be initiated through the study of collections, which for some reason or other can not be pursued without field work and further studies, can be carried on either by the parent Institution or by some other branch of it. From this point of view the fact that the Institution, Museum, and Bureau of Ethnology are in one organization has produced most useful results, and it is not improbable that in the future other combinations which may be of great advantage to the scientific work of the Government and the advancement of science generally, can be effected without in any way interfering with the fundamental purpose of the Museum.

NATIONAL GALLERY OF ART.

The brief history of the inception of the National Gallery of Art, of the tender and acceptance of the Freer collection and of the decree of the supreme court of the District of Columbia, resulting in the securing of the Harriet Lane Johnston collection, is given in the report for the previous year. As described more in detail in the report on the National Museum, these collections have been temporarily installed in the lecture hall of the Museum, and, in spite of the fact that the place was not designed for a collection of art, have been viewed by a large number of visitors. Twenty-one paintings of merit from the Lucius Tuckerman collection have been received on deposit, and gifts have been received, among others, from the Hon. J. B. Henderson, the chairman of the executive committee of the Board of Regents, and from Miss Eleanor Blodgett, of New York.

A most considerable gift, especially gratifying in view of the fact that it furnishes an index of real recognition of the importance of

the National Gallery on the part of a distinguished collector, was the donation by Mr. William T. Evans, of Montclair, N. J., of 52 paintings in oil by American artists of established reputation. No space was available for the installation of this really exceptional collection in the buildings of the Institution or Museum, and, through the courtesy of the trustees of the Corcoran Gallery of Art, the paintings have been temporarily hung in that gallery.

With a view to providing space for the National Gallery for a period of years and until a proper building is secured, I have included in the estimates for the coming fiscal year an item for adapting the large second story of the main part of the Smithsonian building, a hall 200 feet long and about 50 feet wide, for this purpose. It will require some changes to make it suitable for the hanging of pictures, and improvements must be made in the approaches, which are now inconvenient for the public. I trust that Congress may see its way to grant this appropriation at its forthcoming session.

The tender of the deposit of 13 paintings by Edward Moran, illustrating American history, made by Mr. Theodore Sutro, of New York, was accepted, and in September, 1907, this interesting historical collection was hung on screens especially built for the purpose.

The responsibility assumed by the Institution for the nation in bringing together a worthy gallery of art has created widespread interest and comment in magazines and journals on the part of artists and art critics and with hardly an exception has been cordially received. The Institution recognizes the deep responsibility entailed by this new movement and fully appreciates that the art world and the public have a right to expect that the future gallery shall be worthy of the nation. Mr. Rathbun has taken deep interest in the promotion of the gallery and has given a great amount of personal attention to it, and Mr. W. H. Holmes, a member of the staff, and himself a professional artist, has given valuable advice in the matter of selection and installation. It will of course be a considerable time before the Institution can command the services of a staff experienced in the fine arts. But there seems to be no reason why the principles which have for years guided the Institution in administering upon scientific matters should not be applied with equal success to the fine arts. The Secretaries have never relied exclusively upon their own judgment, nor even upon the judgment of the very able staff, to pass upon scientific memoirs or to administer funds for scientific purposes, but they have been aided by committees composed of the most distinguished specialists throughout the country. Hardly a single scientific man through the course of more than half a century has ever declined to act upon such a committee, and it would seem feasible to try out the suggestion informally made to the Board of Regents by Rathbun nearly a year ago, that the acceptance of paintings and

indeed the general policy of the National Gallery of Art should have the advice of a committee composed of the most distinguished artists, sculptors, and students of art in the country, which body might, for purposes of administration, be divided into subcommittees to deal with the various aspects of the National Gallery. Steps have already been taken to organize such a committee, and conferences have been held looking to that end, and I hope before very long to bring a definite plan for its constitution to the attention of the Regents.

BUREAU OF AMERICAN ETHNOLOGY.

The Bureau of American Ethnology has been engaged in investigations among the Indian tribes of the country for upward of a quarter of a century. The object of these investigations has been twofold—to preserve a record of the native races of this country, and to place at the disposal of the General Government information which would enable it successfully to deal with the tribes. For this latter work the first requisite is a working knowledge of the tribes, and the Bureau has collected data relating to some 60 families of linguistic stocks, and upward of 300 tribes. It has located and classified these, and has made progress in the study of their history, relationships to one another and to the whites, their needs as wards of the Government, and their capacities for and adaptability to civilization. For this purpose it was deemed necessary to give attention to the culture of the tribes, especially their languages, social organization and government, systems of belief, religious customs, and arts and industries, as well as to their physical and mental characteristics.

It has not been possible to study all of the tribes in detail, but only to investigate a sufficient number as types to stand for all. The results of the work heretofore accomplished are embodied in published reports, and in many manuscripts preserved in the archives of the Bureau. It has been deemed advisable to take stock, as it were, and to issue a summary of our present knowledge of the tribes. This has taken the form of a handbook of American Indians, the first volume of which has appeared and received much favorable comment. No effort will be spared to push this work to a conclusion, and as much force and time as are necessary for this purpose will be employed during the year. In order to keep this summary within the compass of an easily consulted handbook, many important subjects have been treated merely in outline.

The next special subject to which a publication will be devoted will be the languages and their dialects, for which a handbook in at least two volumes is in progress, the first being now ready for publication. It is the work of our first American philologist, assisted by

a score of the ablest students of this branch in the United States. The arts and industries will also be treated in a separate handbook now under way, and other branches are likewise in preparation for publication. These include treaties and land sessions, sign language and pictography, religions, social systems and government, physical and mental characteristics, archeology, and other subjects.

This work of studying and recording the Indian tribes is not only of national importance, but urgent. It can never be repeated. It will constitute the only systematic record of the red race that can ever be made. The native race, one of the four races of men, is disappearing, and the processes of obliteration are irresistible and swift. A language or culture of any race, once destroyed, can never be recovered. The work is worthy of a great nation, and is one that can be carried on systematically only by the Government. The Government has two great obligations which the Bureau is rapidly fulfilling: (1) To know the Indian for practical purposes of government and in the interests of humanity; (2) to preserve to the world an adequate record of the race which is so rapidly disappearing.

With the object of assisting the departments of the Government having custody of the public domain in the preservation of antiquities, the work of compiling a descriptive catalogue of antiquities has been continued, and several bulletins relating to this work have been published.

Uniform rules and regulations have been adopted by the three departments in control of the public domain in carrying out the recently enacted law for the preservation of antiquities. Under this law three important archeological sites were declared national monuments, as follows: Chaco Canyon in New Mexico, including several important ruined pueblos; El Moro, New Mexico, commonly known as Inscription Rock, and Montezuma Castle, in Arizona, an important cliff ruin.

INTERNATIONAL EXCHANGES.

The work of the International Exchange Service continues to increase from year to year, until the number of packages annually passing through the hands of the service now amounts to nearly 200,000, and the weight to over 200 tons. During the past year nearly 2,000 packing boxes were required in transmitting exchanges to other countries. These figures serve to convey some idea of the magnitude of the operations of the service and make apparent the need of increased appropriations from time to time in order to keep the work up to the high standard of efficiency which has been attained. A larger appropriation was therefore requested for carrying on the service during the coming year, and it is gratifying to state that Congress granted $32,200, an increase of $3,400 over the sum allowed for the year now closed. This additional amount will per-

mit further improvements in the service and renewed exertions to procure larger returns of government publications from abroad for the Library of Congress and the several Departments and Bureaus of the Government.

The Smithsonian Institution, through its system of exchanges, is in correspondence with 58,107 establishments and individuals, 46,514 of which are exterior to the borders of the United States. As will be seen from a perusal of the table in the full report on the exchanges in the appendix, these correspondents are scattered throughout the world, and it may be said that there is no place, however remote, which does not profit by the service.

Under the Congressional resolutions of March 2, 1867, and March 2, 1901, setting apart a certain number of documents for exchange with foreign governments, there are now sent regularly to depositories abroad 53 full sets of United States official publications and 30 partial sets, the governments of Ecuador, Panama, and Alberta, Canada, having been added to the depositories of partial sets during the past year.

In order to prevent loss of publications intended for Government establishments, special attention has been given to foreign consignments of books arriving at the various United States custom-houses incorrectly or insufficiently addressed. During the past year these efforts have resulted in the clearing of a number of consignments which might otherwise have gone astray.

The work of increasing the office collection of directories and other books of addresses has continued during the year, and has resulted in the accumulation of a very creditable assemblage of such publications.

I am gratified to state that through the efforts of Dr. Eypaldo Bassier, a member of the Greek Parliament, an arrangement has been effected whereby all exchanges for Greece may now be forwarded to the National Library at Athens for distribution, instead of limiting the consignments, as formerly, to publications intended for Government institutions or individuals connected with them. This arrangement will enable the Institution to make more frequent transmissions.

Recently a communication was received from Dr. F. Bonola Bey, secretary-general of the Khedivial Geographical Society in Cairo, stating that on account of absence from Egypt it would be necessary for him to discontinue the distribution of exchanges for the Institution; adding, however, that the director-general of the survey department at Cairo would take charge of the work. A letter from the director-general has since been received placing the services of the department at the disposal of the Institution. Consignments will therefore be sent to the survey department in the future.

Transmissions to Bulgaria, which were temporarily suspended on account of the death of Dr. Paul Leverkühn, who attended to the

distribution of exchanges for that country, have been resumed. The Prince of Bulgaria, in response to a request of the Institution, has designated the Scientific Institutions and Library of Sofia to act as the exchange intermediary between Bulgaria and the United States.

As Hawaii, the Philippine Islands, and Porto Rico are under the jurisdiction of the United States, the Institution feels that exchanges with them can no longer be termed "international," and has therefore discontinued the acceptance of packages from domestic sources for these territories.

The International Exchange Service, in its efforts to aid the California Academy of Sciences in the rehabilitation of its library and collections, destroyed by the earthquake and fire of April, 1906, sent circulars to all the foreign correspondents of the academy soliciting contributions. I am gratified to state that a most liberal reponse has been made, the number of exchanges received aggregating 6,370 packages and publications, which were forwarded to San Francisco. It may be noted in this connection that this is the first time since its organization that the Exchange Service has sent out a circular of this character in behalf of any establishment.

NATIONAL ZOOLOGICAL PARK.

By act of Congress approved April 30, 1890, the National Zoological Park was established "for the advancement of science and the instruction and recreation of the people," and in pursuance of this authorization the collection of living animals has increased from year to year, it being the purpose to exhibit living species of the various types of animal life for the instruction and entertainment of the public.

In carrying out the first of the objects stated in the act of organization, namely, the advancement of science, the original design contemplated the establishment of methods of scientific research, but lack of means, and the more important necessities of the park, have prevented this from being realized. Plans for a laboratory are in hand. The varied zoological collection now assembled affords material of great value for studying the habits of animals, and for physiological and pathological research, subjects of practical importance and utility.

Much care and attention has also been devoted to preserving the natural beauty of the surroundings and to the enhancing of the attractiveness of the park to visitors.

With a single exception, no especial appropriation has been made for the erection of buildings for the animals in the park since its i tion. They were originally housed in wooden sheds which have adually replaced by fireproof structures, as the appropriations

permitted. This plan will be continued. It has not been carried forward as rapidly as the necessities demand, owing to the fact that the appropriation granted, for a number of years, has been but little more than sufficient for the maintenance of the park.

Attention has before been called to the desirability of securing for the park the narrow tracts of land lying between its boundaries and the recently established highways on the southeast and west. The highways were located by the Engineer Commissioner of the District as close to the park as the topography would permit, in order to reduce these tracts to a minimum. It is estimated that the land in question can be acquired by condemnation for $40,000, and an item for this purpose is submitted in the estimates.

The collection of animals at the close of the fiscal year numbered 1,193. The small mammal house, which has been under construction for several years, was opened to the public on November 15. To it were transferred the collection of monkeys, as there had always been a difficulty in keeping these animals in the proper condition of health in their previous quarters. Work upon two additional bear yards has been contracted for and considerable repairs made to some of the older cages. The Adams Mill road was overhauled and resurfaced during the autumn of 1906, and the planting of trees was carried on at suitable times as far as the available fund permitted. Five of the more important buildings were heated from the central heating plant, installed during the previous year. The specialists of the Department of Agriculture were offered opportunities for pathological studies when animals died, and such dead animals as might be useful to the national collections were sent to the National Museum.

ASTROPHYSICAL OBSERVATORY.

The work of the Astrophysical Observatory, carried on under the supervision of Mr. C. G. Abbot, who was appointed director March 1, 1907, has consisted of observations at the Mount Wilson Observatory and at Washington, and the preparing of Volume II of the Annals of the Observatory. About seventy days on Mount Wilson were devoted to observations of the "solar constant" of radiation, on which the staff of the observatory had been at work for some years. The results were generally excellent. A new continuous recording pyrheliometer is in course of construction for this work, of different dimensions and construction from the one at present in use. Much attention was paid to the observation of the intensity of light reflected from clouds, with a view to the determination of the albedo or total reflection of the earth. The quality and amount of the light of the sky was also measured on several days.

Measurements for the determination of the "solar constant" were also made at Washington whenever atmospheric conditions permitted. These are of great value as supplementary data to the Mount Wilson observations.

Volume II of the Annals is in press, and includes an account of the work of the observatory from 1900 to 1907. Speaking broadly, the energy of the observatory has been devoted to an investigation of the intensity of the rays of the sun and the dependence of the earth's temperature upon the radiation.

The investigations have resulted in apparently definitely fixing the approximate average value of the "solar constant" at 2.1 calories per square centimeter per minute, and in showing decisively that there is a marked fluctuation about this mean value, sufficient in magnitude to influence very perceptibly the climate, at least of inland regions, upon the earth.

The observatory buildings, although temporary, have been kept in good repair by a small expenditure. Plans have been made and contracts have been awarded for the installation of electrical lighting and power to replace the present inadequate facilities, and some additions have been made to the research equipment and library.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

The International Catalogue of Scientfic Literature is a classified author's and subject catalogue of all original scientific papers published throughout the world. The organization consists of bureaus, established in each of the civilized countries, whose duty it is to furnish references to the scientific publications issued within their several regions, these references being assembled, edited, and published in seventeen annual volumes by a central bureau in London.

The cost of printing and publishing is met by the subscribers to the Catalogue; and American universities, libraries, and scientific societies alone have shown their appreciation of the work by making advance subscriptions amounting to over $30,000. The cost of collecting and indexing the material for the Catalogue is in each case borne by the countries taking part in the work, and is for the most part derived from direct governmental grants.

The Regional Bureau for the United States was organized in 1901 by the Smithsonian Institution, and was maintained by funds of the Institution until it was placed on a firm footing by an appropriation
ı le by Congress of $5,000, which became available for use July 1,
: 06. A further grant of $5,000 became available July 1, 1907.
h ı o bureau collects, indexes, and classifies the current sci-
li ure published within the country it represents, and fur-
material to the central bureau in London for publication.

The citations are secured by regularly going through all of the journals listed for examination, by a daily search through the publications which are received by the Smithsonian Institution, and by examination of all available sources. Lists of all papers indexed are also from time to time submitted for revision directly to the authors whose names appear on the records. The authors are requested to send separates of their work for the use of the Catalogue, a practice which results incidentally in considerable accesisons to the library.

It has been hoped that the material collected by the Bureau could be printed separately as a current classified index of American Scientific Literature, which would make it available for American men of science probably a year before the International Catalogue was published, but since the printing would have to be done at the expense of the fund of the Institution, it was decided after thorough consideration that the outlay could not at present be justified.

NECROLOGY.

During the year the Institution has suffered the loss of a Regent and of three able members of its staff. The Hon. R. R. Hitt, distinguished for his services in the diplomatic corps and as a Member of Congress, where he ably served for many years as chairman of the Committee on Foreign Affairs, a man of cultivation and broadly interested in science and art, passed away on September 20, 1906. He was appointed a Regent on August 11, 1893, and served continuously until his death and acted since 1901 as a member of the executive committee. In the Proceedings of the Board of Regents, printed in another place, there will be found an appropriate tribute to his memory by his colleagues.

One of the oldest members of the administrative staff of the Institution, William Jones Rhees, died March 18, 1907. Mr. Rhees was born March 13, 1830. In 1852 he became chief clerk of the Institution, and in that capacity, and later as keeper of the archives, served it with a brief interruption until the time of his death. His knowledge of the affairs of the Institution was wide, and with him there passed away the principal human repository of its history, for he had been connected with it almost since its inception and had served during the greater part of the administrations of Secretaries Henry, Baird, and Langley. He was a methodical man, and in addition to his administrative labors issued publications valuable to the librarians of the country and others of importance on the history of the Institution and its founder. He was a public-spirited citizen, and his deep devotion to the Institution is evidenced by a bequest from his modest estate.

Albert S. Gatschet, a distinguished linguist and for many years connected with the Bureau of American Ethnology, died on March

16, 1907. An appreciative account of his career will be given in the annual report on the Bureau of American Ethnology.

Paul Edmond Beckwith, Assistant Curator of History in the National Museum, died on June 27, 1907. A sketch of his career is given in the report on the Museum.

LANGLEY MEMORIAL MEETING.

On December 3, 1906, a meeting in memory of the late Secretary Samuel P. Langley, was, in accordance with a resolution of the Board of Regents, held in the lecture hall of the National Museum. The Chancellor of the Institution, the Hon. Melville W. Fuller, Chief Justice of the United States, presided, and after preliminary remarks introduced the speakers: The Hon. Andrew D. White, who presented the memoir on behalf of the Board of Regents; Prof. E. C. Pickering, director of Harvard College Observatory, who described Mr. Langley's contributions to astronomy and astrophysics; and Octave Chanute, esq., of Chicago, who spoke on Mr. Langley's contributions to aerodynamics.

The addresses delivered on that occasion, together with a bibliography of the published works of Mr. Langley, have been issued by the Institution in the series of Smithsonian Miscellaneous Collections, and also in a special edition.

Respectfully submitted.

CHAS. D. WALCOTT, *Secretary.*

APPENDIX I.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

SIR: I have the honor to submit the following report on the operations of the United States National Museum for the fiscal year ending June 30, 1907:

The most noteworthy feature of the year was the decided advance made in the subject of the fine arts, so marked indeed as to call for immediate action in providing at least a temporary home for the national gallery, whose nucleus already gathered has received much favorable comment. While the erection of the new building for the Museum has been retarded by delays in the delivery of granite, the work has proceeded steadily and otherwise satisfactorily. The collections were increased by about a quarter of a million specimens, including a large amount of material of exceptional importance. The classification and arrangement of the additions were carried forward as rapidly as possible under the present limitations as to means and space, and the collections as a whole have been maintained in good condition.

NATIONAL GALLERY OF ART.

The Congressional act of 1846, founding the Smithsonian Institution, provided that all objects of art belonging to the United States should be delivered into the custody of that establishment whenever suitable arrangements could be made from time to time for their reception. The formation of a national gallery of art thus intrusted to the Institution received early and favorable consideration by the Board of Regents and was embodied in the plan of organization. It was the sentiment of the Board that the gallery should include both paintings and sculpture as well as engravings and architectural designs, that studios for young artists should be provided, and, as it was expected that the collections would accumulate slowly, that the gallery should be partly used during the winter for loan exhibitions.

In the Smithsonian building, which was immediately put in course of erection, two rooms were especially designed for the collections of art, the west hall and connecting range on the main floor. These quarters were so used for a time in conjunction with the library and reading room, but the accommodations thus afforded proved so inadequate that it became necessary to also devote to the same purpose a part of the large upper hall now occupied by the collection of prehistoric archeology.

Examples of art were among the very first acquisitions by the Institution, and from time to time thereafter additions of one kind and another were received, but any sum that might have been spared for this purpose from the Smithsonian income would have been wholly insufficient to make any pronounced or systematic advance in this direction. In the National Museum, however, certain branches of art have been fostered for over a quarter of a century and are now fairly well represented.

The first collection purchased by the Institution was the valuable series of prints assembled by the Hon. George P. Marsh, containing examples of the work of nearly every etcher and engraver of celebrity from the early masters to the middle of the last century. It was recognized as the choicest collection of its kind then in this country. Later accessions included, besides engravings,

a number of paintings, reproductions of celebrated pieces of sculpture, busts of distinguished individuals, and many important books on art.

The early exhibition in the upper Smithsonian hall consisted mainly of the unique collections of Indian portraits and scenes by J. M. Stanley, C. B. King, and others, but in the fire of 1865 this section of the gallery with its contents was entirely destroyed. The objects on the lower floor escaped injury and were subsequently deposited for safe-keeping in the Library of Congress and the Corcoran Gallery of Art, where they remained until about ten years ago. Since that time one of the rooms in the eastern part of the Smithsonian building has been utilized for the prints, books, and various other works of art, but the larger part of the collection has been provided for in the National Museum.

Such, briefly, was the history of the art exhibits up to January, 1906, when the acceptance by the Board of Regents of the large and notable collection of Mr. Charles L. Freer marked the beginning of a new epoch in the affairs of the gallery of art. In the following July a further advance was made through the acquisition of the valuable collection of the late Harriet Lane Johnston, based upon a decision of the supreme court of the District of Columbia, essentially reaffirming the intent of the fundamental act, already referred to, that the custodianship of the national gallery of art was vested in the Smithsonian Institution. This collection is especially noteworthy in that it contains paintings by several celebrated masters, besides other pieces of merit and of historical importance. It was delivered to the Institution in the early part of August, 1906, and was at once installed in the reception room in the Smithsonian building, the only place then available.

The necessity of securing more extensive quarters without delay led to the selection and temporary fitting up of the lecture hall in the Museum building for the purposes of the gallery and especially for the paintings. On the completion of these changes in the latter part of November, 1906, the Harriet Lane Johnston collection and other paintings were transferred there, and these, with several loans and donations, fully occupied the existing wall space. Among the loans should be mentioned 21 paintings from the Lucius Tuckerman collection, and among the gifts, one by the Hon. J. B. Henderson, of Washington, and one by Miss Eleanor Blodgett, of New York.

During the latter part of the winter the gallery received a most substantial and gratifying recognition from Mr. William T. Evans, of Montclair, N. J., the well-known connoisseur and patron of art, whose contribution, made without solicitation, consisted of 52 paintings in oil by American artists of established reputation. Unfortunately no place could be found in the Museum building for this valuable collection, and it was necessary to provide elsewhere for its temporary keeping. This has been accomplished through the courtesy of the trustees of the Corcoran Gallery of Art, where the pictures are now hung, filling the greater part of the large atrium.

Leaving out of consideration the Freer collection, which is to remain at the home of its generous donor during his lifetime, the national gallery now has in its possession valuable paintings and other art objects for whose exhibition under suitable conditions it is important to arrange without delay. For this purpose there is no better place in the existing buildings than the second story of the main part of the Smithsonian building, a hall 200 feet long by 50 feet wide. It will require some changes to adapt it to the hanging and lighting of pictures, and some improvement in its approaches which are now inconvenient for the public, involving an expenditure greater than is possible from the current appropriation, but it is hoped that Congress may provide for this work at its forthcoming session.

BUILDINGS.

At the beginning of the last fiscal year, work on the new building for the Museum had progressed to the extent of completing the basement walls and piers and the steel framework and brick arches resting upon them, except at the south and north pavilions. The court walls of the main story had also been started. From that time onward the construction of the building would have advanced more rapidly but for delays in the delivery of the granite. Instead, therefore, of being ready for the roofs at the end of the fiscal year, as had been expected, the outer walls have been carried only to the height of the lintels at the top of the second story on the eastern section of the building, and not so high on the western section. The two entrance pavilions have only reached the top of the basement floor, but the steel work and arches of the second floor are in place and the basement lecture hall has been inclosed and partly vaulted and tiled. With the receipt of the final shipment of the white Bethel granite all troubles in the matter of construction should be ended, as there have been no delays in the fulfillment of all other contracts for supplies, and the stone for the upper story has been on hand for several months.

The retardation in the erection of this building has rendered difficult the administration of the Museum, since the overcrowding of the present buildings and outside rented quarters by the immense and invaluable collections has introduced several elements of danger which can only be obviated by the occupancy of the new structure.

The rebuilding of the roofs of the present Museum building, without serious derangement of the collections, was successfully continued. Contracts have been made for the replacement of four additional roofs during the new year, leaving only the roof of the central rotunda to be provided for thereafter.

Progress was also made in the isolation of the several exhibition halls with the view of obtaining greater fire protection, this work consisting in the filling in of the large arched openings between the halls with fireproof materials, a plan which should be continued each year to the extent possible with the funds available.

ADDITIONS TO THE COLLECTION.

The number of accessions received during the year, not including the subject of the fine arts, was 1,398, comprising a total of about 250,000 specimens, of which nearly 4,000 were anthropological, 145,000 biological, and over 100,000 geological and paleontological.

The principal additions in ethnology came from the Congo region of Africa and the Philippine Islands. Among the more notable smaller ones were baskets and lace of Malacca workmanship, rare Chilcootin baskets, and examples of rich old embroideries. The most important accessions in prehistoric archeology comprised several hundred implements, vessels, examples of fabrics and basket work, and skeletal remains, obtained during excavations at Casa Grande, Arizona, under the direction of the Smithsonian Institution, and a large number of earthenware and stone objects of various kinds and uses from Panama, Costa Rica, Guatemala, Honduras, Mexico, and the State of Tennessee. Of European origin were stone implements and fragments of Romano-British urns from near Norfolk, England, and flint implements from La Quina, France. Examples of Greco-Egyptian papyri and other interesting objects were secured for the division of historic archeology. The additions in physical anthropology consisted chiefly of a large series illustrating the principal types of normal variations in the human skeleton, a number of skulls of the extinct Huron Indians, and many specimens of the brains of various animals prepared for comparative purposes.

The division of technology was especially enriched in the subject of firearms, mainly through the courtesy of the War Department. This division now possesses the finest historical collection in existence of the rifles, muskets, carbines, pistols, etc., of the colonial period and the military service of the National Government. The collection is supplemented by extensive data gathered as a basis for a comprehensive study of the subject. Other noteworthy contributions to the division included a series of models from the Department of the Interior, representing important historical inventions, the earliest dating from before the Christian Era; a number of pieces of apparatus devised by Mr. Emile Berliner, illustrating important early steps in the development of the telephone; and the Santos Dumont airship No. 9. The division of ceramics received many fine specimens of pottery from Japan and the United States; the division of graphic arts, examples of binding by the St. Hubert Guild of Art Craftsmen and of color photography; the section of musical instruments, one of the earliest church organs brought to this country; and the section of medicine, a series of enlarged photographs of the more eminent of American physicians and surgeons.

The historical collections were increased by a number of important gifts and loans, the most noteworthy consisting of some of the early physical apparatus devised by the late Secretary Langley, and the many medals and diplomas awarded him for his distinguished services in the advancement of science, all of which have been installed in an appropriate case in the hall of history. The principal additions to the division of historic religions consisted of two loans, comprising a collection of lamps, amulets, and embroideries used in Jewish religious life, and a large series of Chinese and Japanese rosaries.

The transfers from the Bureau of Fisheries constituted in the aggregate the principal accession to the department of biology. They comprised a large collection of marine fishes and invertebrates, with some land animals, from the *Albatross* cruise of 1906 in the North Pacific Ocean and Okhotsk Sea; extensive collections of Japanese fishes and Hawaiian corals and hydroids, including many rare and recently described species; over 3,000 specimens of fishes from the fresh waters of West Virginia, and other valuable material. Maj. E. A. Mearns, surgeon, U. S. Army, who has been stationed in the Philippine Islands, forwarded an extensive series of mammals, birds, reptiles, fishes and mollusks, obtained mainly on certain of the smaller and less known islands, and containing some new genera and many new species.

Noteworthy contributions of mammals were received from Venezuela, Cuba, and the Kiu-siu Province of China; of birds and birds' eggs from Costa Rica and elsewhere; of reptiles and batrachians from Europe, Patagonia, Cuba, and Virginia; and of fishes from Australia and the Philippines, the latter through the Philippine Commission to the St. Louis Exposition. The total number of specimens of fishes acquired was about 25,000. The division of mollusks obtained some 800 species from the Philippines and Eastern Asia, many being types of species described by Moellendorf; a large collection of fresh-water forms from the vicinity of Wilmington, N. C., including a good series of the rare *Goniobasis magnifica*, and many interesting land shells from Central America. The additions in entomology comprised about 44,000 specimens, including 20,000 Coleoptera from Dr. D. R. Uhler, of Baltimore; 8,000 of Lepidoptera from Mr. William Schaus, and over 6,000, representing various groups, from the Department of Agriculture. Besides the transfers from the Bureau of Fisheries, the division of marine invertebrates received extensive series of corals from Hawaii and French Somaliland, and 238 microscopic slides of keratose sponges from Doctor Von Lendenfeld. The helminthological collection was increased by over 500 specimens from the Bureau of Animal Industry and the Public Health and Marine-Hospital Service.

The division of plants received about 47,000 specimens, mainly from the following sources: The West Indies, and especially Cuba, over 6,000 specimens; Central America, about 1,400 specimens; Mexico, 2,200 specimens; the Philippine Islands, 5,571 specimens; District of Columbia, about 5,000 specimens; from different localities, through the Department of Agriculture, over 4,000 specimens; the private herbarium of Mrs. J. N. Milligan, of Jacksonville, Ill., comprising about 2,200 specimens; and the collection of the late Prof. T. A. Williams, numbering about 4,400 specimens.

One of the most noteworthy accessions in geology consisted of a large amount of material obtained by the head curator during an investigation of Coon Butte, Arizona. The Geological Survey transmitted a large number of rocks and ores from Wyoming, Colorado, Washington, Arizona, and Maine, and material of the same character as well as minerals were obtained from other sources. The collection of meteorites was increased by seven specimens.

The additions in paleontology were exceptionally large and valuable, the more important comprising about 45,000 specimens from the Pre-Cambrian, Cambrian, and Ordovician horizons in the United States, transferred by the Geological Survey; the Pate collection of about 50,000 specimens from the Paleozoic rocks of the Mississippi Valley, and several hundred specimens from the Devonian of Missouri, both presented by the Hon. Frank Springer; the Nettleroth collection, containing practically all of the many types figured in that author's Kentucky Fossil Shells; and an especially fine representation of the Silurian and Devonian faunas of Indiana and Kentucky.

EXPLORATIONS.

While no extensive field work was carried on directly by the Museum, several expeditions, both for collecting and observation, were made by members of the staff, as follows: Doctor True in Maryland, Doctor Stejneger in Virginia, Doctor Bartsch in North Carolina, Mr. Bean in Florida, Mr. Hahn in Indiana, Doctor Dyar and Mr. Caudell in California, Doctor Rose in Mexico, Mr. Maxon in Cuba, and Doctor Merrill in Arizona. Mr. Charles W. Gilmore, of the department of geology, was sent by the Smithsonian Institution to Alaska to search for the remains of large fossil mammals, while Doctor Bassler and Doctor Peale were detailed to field work in conjunction with the Geological Survey. The explorations by which the Museum was mainly benefited were, as heretofore, those of the Geological Survey, the Department of Agriculture, the Bureau of Fisheries, and the Bureau of American Ethnology. Mention should also be made of the personal field work in the Philippines of Doctor Mearns, of the Army, and in Malaysia of Dr. W. L. Abbott; and also of the excavations by Doctor Fewkes at Casa Grande, Arizona, under a special act of Congress.

CARE AND CLASSIFICATION OF THE COLLECTIONS.

The reorganization of the osteological collection in physical anthropology, which comprises parts of about 8,000 skeletons, was completed during the year. Doctor Hrdlička, the assistant curator in charge of this division, has carried on investigations relating to the crania and skeletons of Indians and the orang, and to the brain in the higher vertebrates, including man. An extension of storage space has permitted the classified arrangement of a much greater number of objects of ethnology than heretofore. Professor Mason and Doctor Hough were mainly occupied in working up the ethnological collections from Malaysia, and the latter also continued the preparation of his report on the Museum-Gates expedition of 1905 in Arizona, and on the Pueblo collections in the Museum. Doctor Casanowicz has begun a descriptive account of the exhi-

bition of Jewish religious rites and ceremonials, which is probably the finest in the country.

Some changes and improvements are to be noted in the storage and classification of several groups of mammals and birds. The systematic arrangement of the reserve series of fishes has been continued, and fair progress has been made in the installation of the new system of steel racks and hard-wood drawers for insects. The labeling and registering of marine invertebrates has kept pace as nearly as possible with the receipt of material, and much has been done toward completing the card catalogue of identified specimens. In April, 1907, two assistants were detailed to the Yale University Museum to engage in separating the large collection of marine invertebrates from the earlier Fish Commission explorations, which have remained in the charge of Prof. A. E. Verrill. The first set of duplicates will become the property of Professor Verrill, the reserve series and other duplicates coming to the National Museum.

The researches by members of the zoological staff and others were extensive and varied, the principal subjects being briefly as follows: Fossil cetaceans, by Doctor True; the birds of North and Middle America, by Mr. Ridgway; and those of Malaysia and the China Sea, by Mr. Oberholser; the reptiles of Japan, the Philippines, West Indies, and Costa Rica, by Doctor Stejneger; fishes from Argentina, the Philippines, and the west coast of North America, by Professor Evermann; from the Philippines, by Mr. Bean and Mr. Seale; and from the Pacific region generally by Doctor Jordan and Doctor Gilbert; a monograph of the mosquitoes by Doctor Dyar; the Pyramidellidæ of Oregon, by Doctor Dall and Doctor Bartsch; crabs of North America, the North Pacific Ocean, and the Gulf of Siam, by Miss Rathbun; isopods of the North Pacific Ocean, by Doctor Richardson; the entire Museum collection of stalked barnacles, by Doctor Pilsbry; the crinoids from the North Pacific Ocean and elsewhere, by Doctor Clark.

The systematic rearrangement of the herbarium, which has been in progress for several years, was nearly completed, and experiments were carried on looking to the construction of fireproof herbarium cases for the new building. Doctor Rose continued studies on Mexican plants and the cacti, Mr. Maxon on American ferns, and Mr. Painter on water lilies.

The principal routine work in the department of geology comprised the systematizing of the petrographic material recently received, the separation of duplicates from the reserve series, the renovation of the exhibition series of minerals and gems, the arrangement of the Pate and Ulrich collections of fossil invertebrates, and the working out of specimens, and the designation of types and illustrated specimens of fossil vertebrates. Doctor Merrill, in collaboration with Mr. Tassin, made studies upon meteorites and associated phenomena, and many specimens of minerals were identified. The investigations by Doctor Bassler related mainly to the bryozoa and ostracoda of several geological horizons, and those of Mr. Gidley and Mr. Gilmore to both mammalian and reptilian forms.

EXHIBITION COLLECTIONS.

The crowded condition of the public halls has rendered it impossible for several years past to make any material additions to the exhibition collections, and practically nothing more can be done in this direction until the new building has been completed. During the past year, however, an interesting series of specimens has been made accessible to the intelligent visitor in the laboratory of physical anthropology. A group of Roumanian peasants has been installed in the west hall, and a number of recently acquired antiquities have been provid for in the hall of archeology. The entire collection of firearms has been t together in the east hall, in which also one of the original Lilienthal

flying machines has been suspended from the roof. The additions in zoology have consisted mainly of mammals and insects, and in geology of fossil vertebrates, rocks, and minerals. As explained elsewhere, the lecture hall is now temporarily occupied by the National Gallery of Art.

MISCELLANEOUS.

Of duplicate specimens separated from the collections in the course of recent investigations, about 16,000 were distributed in 208 sets to educational establishments in different parts of the United States and about 25,000 were used in making exchanges with other establishments and with individuals. Over 6,000 specimens were lent to specialists for study.

The publications issued during the year were the annual reports for 1905 and 1906; volumes 31 and 32 of the Proceedings; the second volume of Bulletin 53, completing the catalogue of type and figured specimens in the department of geology; Part I of Bulletin 56, on the mammals of the Mexican boundary of the United States; Bulletin 57, on the families and genera of bats; a supplement to Bulletin 51, being a list of the publications of the Museum from 1901 to 1906; Volume XI of the Contributions from the National Herbarium, consisting of a single paper entitled "The Flora of the State of Washington," and three parts of Volume X of the same series, relating mainly to the botany of Mexico, Central America, and the Philippine Islands. The following bulletins were in print at the close of the year, but were not issued until early in July: Part IV of Bulletin 50, the Birds of North and Middle America; Bulletin 58, Herpetology of Japan and Adjacent Territory, and Bulletin 59, "Recent Madrepora of the Hawaiian Islands and Laysan." A number of short papers based on collections in the Museum were also printed in the quarterly issue of the Smithsonian Miscellaneous Collections and elsewhere.

The additions to the library of the Museum comprised 2,581 books and 3,567 pamphlets and periodicals. The total number of pieces recorded in the library at the close of the year was 30,307 volumes, 47,642 unbound papers, and 108 manuscripts.

At the Jamestown Ter-Centennial Exposition, which opened on April 26, 1907, the subject assigned to the Museum, namely, the aboriginal, colonial, and national history of America, has been as fully illustrated as the means and space permitted. The collection comprises prehistoric Indian implements; representations of the native arts of Alaska, Porto Rico, Hawaii, Samoa, and the Philippine Islands; pictures, relics, and models illustrating the different historic periods of the country, land and water transportation, the invention of the telegraph and telephone, and the firearms used by the United States Army. The central feature is a life-sized group, depicting Capt. John Smith and his men in a small sailboat trading for corn and skins with the Powhatan Indians at the mouth of the James River.

The Museum has also taken part in the International Maritime Exposition at Bordeaux which opened on May 1, although the exhibit of the United States was not finally installed until about the 1st of July. The objects supplied by the Museum consist of a number of models illustrating the water craft used by the aborigines of the Western Hemisphere and illustrations and models of the earlier steamboats, including those of John Fitch and Robert Fulton.

Respectfully submitted.

RICHARD RATHBUN,
Assistant Secretary, in Charge of U. S. National Museum.

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

APPENDIX II.

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY.

SIR: I have the honor to submit the following report on the operations of the Bureau of American Ethnology for the fiscal year ending June 30, 1907:

SYSTEMATIC RESEARCHES.

The operations of the Bureau of American Ethnology, conducted in accordance with the act of Congress making provision for continuing researches relating to the American Indians under direction of the Smithsonian Institution, have been carried forward in conformity with the plan of operations approved by the Secretary July 19, 1906.

Systematic ethnological researches have been prosecuted by the scientific staff of the Bureau, assisted by a number of collaborators who have been invited to conduct investigations for which they were especially qualified. The Bureau's scientific staff is restricted to a small number of investigators whose field of labor is necessarily limited, and it has always been the policy of the Bureau to widen its scope by enlisting the aid of specialists in various important branches. While thus seeking to cover in the fullest possible manner the whole field of American ethnology, it has sought with particular care to pursue only such branches of research as are not adequately provided for by other agencies, public or private. The result sought by the Bureau is the completion of a systematic and well-rounded record of the tribes before the ever-accelerating march of change has robbed them of their aboriginal characteristics and culture.

During the year researches have been carried on in New Mexico, Arizona, Oklahoma, Louisiana, Mississippi, Florida, New York, and Ontario. The field work has, however, not been so extensive as during most previous years, for the reason that a number of the ethnologists had to be retained in the office to assist in the completion of the Handbook of American Indians and in the proof reading of reports passing through the press.

The Chief of the Bureau remained on duty in the office during nearly the entire year. Administrative duties occupied much of his time, but during the winter and spring months he was called upon to assist in the preparation of the exhibit of the Smithsonian Institution at the Jamestown Exposition, and in April in installing this exhibit. The completion of numerous articles for the Handbook of American Indians, the revision of various manuscripts submitted for publication, and the proof reading of reports and bulletins claimed his a ntion. Aside from these occupations his duties as honorary curator of the rti : of prehistoric archeology in the National Museum and as curator of Na l Gallery of Art absorbed a portion of his time. The chief was also n to assist in formulating the uniform rules and regulations required Departments of the Interior, Agriculture, and War in carrying out the

provisions of the law for the preservation of antiquities, to pass upon various applications for permits to explore among the antiquities of the public domain, and to furnish data needful in the selection of the archeological sites to be set aside as national monuments. In addition he was able to give some attention to carrying forward the systematic study of aboriginal technology and art, on which he has been engaged for several years, as occasion offered.

At the beginning of the year Mrs. M. C. Stevenson, ethnologist, was in the Indian village of Taos, New Mexico, continuing her studies of the arts, habits, customs, and language of this tribe begun during the previous year. Although the field was new and the traditional conservatism of the tribe made investigation in certain directions difficult or impossible, much progress was made, and, when the work is completed, results of exceptional value will doubtless have been obtained.

In November Mrs. Stevenson visited Santa Clara pueblo for the purpose of making studies of the people and their culture for comparative purposes, and observations were made of the social customs and religious observances of the people. Afterwards, several days were spent in Santa Fé, examining the old Spanish records preserved in the archives of the Historical Society of New Mexico, with the view of learning something of the early relations of the local tribes with the Spanish invaders and with their Spanish-speaking neighbors of later times. Late in November Mrs. Stevenson visited the pueblo of Zuñi, the site of her former extended researches, and spent some weeks in completing her studies on certain phases of the native ritual and worship, on religious symbolism as embodied in pictography and ceramic and textile decoration, and in the revision of her list of plants employed for food, medicine, and dyes. Numerous photographs and sketches of ceremonials and ceremonial objects were made. A number of changes were noted in the dramas and other ceremonies since her last visit, and Zuñi, heretofore presenting at night the quiet somberness of an aboriginal village, has now, when the dusk falls, the appearance of an eastern town, with many lighted windows. Mrs. Stevenson notes that changes are creeping steadily into all the pueblos, Taos perhaps excepted, and is led to express the earnest hope that the work of investigating the town-building tribes of the Southwest be carried forward with all possible energy.

On April 1 Mrs. Stevenson returned to the office, where, during the remainder of the year, she has been engaged in the preparation of reports on her field researches.

Dr. Cyrus Thomas, ethnologist, has been employed the greater portion of the year in assisting Mr. Hodge on the Handbook of American Indians, not only in the preparation of separate articles, but also in assisting the editor on certain lines of proof reading relating to omissions, uniformity in names, etc. Such time as could be spared from these duties was devoted to the preparation of a Catalogue of Books and Papers relating to the Hawaiian Islands. For this purpose the Congressional and other libraries in Washington were consulted and a short trip to Worcester and Boston, Massachusetts, was made for the purpose of examining the libraries of those cities, which are the chief depositories in the United States of the early publications of the missionaries in Hawaii. The number of titles so far obtained is about 2,000. Doctor Thomas assisted also with the official correspondence on subjects with which he is particularly familiar, his attainments as a student of ancient Mexican writings having proved of special value in the examination of certain manuscripts in the Cakchikel language submitted by the Librarian of the American Philosophical Society of Philadelphia.

During the latter part of the previous fiscal year, in pursuance of his linguistic studies, Dr. John R. Swanton, ethnologist, was engaged in preparing an English-Natchez and Natchez-English analytical dictionary, embodying all the published and unpublished material available—that is, about two thousand words and phrases; he also copied on cards all the words and phrases collected by the late Doctor Gatschet from the Attacapa, Chitimacha, and Tunica Indians. At the beginning of the fiscal year Doctor Swanton was engaged in compiling a dictionary of the Tunica language similar to that made for the Natchez. In the field of general ethnology he excerpted and, when necessary, translated, all the available material bearing on the tribes of the lower Mississippi Valley, and arranged for publication that portion dealing with the Natchez.

On April 3 he left Washington to make investigations among the tribal remnants of Louisiana and Oklahoma, and visited the members of the Houma, Chitimacha, Attacapa, Alibamu, Biloxi, Tunica, and Natchez tribes, and was able definitely to establish the relationship of the Houma to the Choctaw and to identify the Ouspie—a small people referred to by the early French writers—with the Offagoula. From the Tunica and Chitimacha he collected several stories which will be of importance in the endeavor to restore the mythology of the tribes of this area, now almost a blank. In the Cherokee Nation (Oklahoma), contrary to expectation, Doctor Swanton found several persons who still speak the Natchez language. This discovery will necessarily delay the publication of the Natchez material already referred to, but if prompt measures are taken, will insure the preservation of that language in its completeness. At Eufaula (Creek Nation) he made a slight investigation into the social organization of the Creeks—enough to determine that much work still remains to be done in that tribe entirely apart from language. Doctor Swanton returned to the office June 7, and during the remainder of the year was engaged in arranging and collating the material collected by him.

Dr. J. Walter Fewkes, ethnologist, was employed in the office during the first month of the year reading proofs of his articles on The Aborigines of Porto Rico and Neighboring Islands and on Antiquities of Eastern Mexico, for the Twenty-fifth Annual Report of the Bureau. Part of August and all of September were devoted to the preparation of a bulletin on the Antiquities of the Little Colorado. He spent seven months in Arizona, leaving Washington on October 15 and returning the middle of May. During four months he superintended the work of excavation, repair, and preservation of the Casa Grande Ruin, in Pinal County, Arizona, and in March and April visited a number of little-known and undescribed ruins along Canyon Diablo and Grapevine Canyon, gathering material for his bulletin on The Antiquities of the Little Colorado Valley. During May and June he was employed in the office, devoting his time to the preparation of an account of the excavations at Casa Grande. The explorations at Casa Grande were conducted under a special appropriation disbursed directly by the Smithsonian Institution, and Doctor Fewkes's preliminary report has been submitted to the Secretary. It is anticipated that a final report on the work when completed will be published by the Bureau of American Ethnology.

Mr. J. N. B. Hewitt was occupied during the earlier months of the year in preparing and correcting matter for the Handbook of American Indians, devoting special attention to the articles on the Iroquoian family, Iroquois, Mohawk, Montour, Mythology, Nanabozho, Neutrals, Oneida, Onondaga, and Ottawa, and to the lists of towns formerly belonging to the Iroquois tribes.

From the 20th of January to the 23d of March, 1907, he was engaged in field work among the Iroquois tribes in New York and in Ontario, Canada. The entire period was devoted to collecting texts in the Onondaga and Mohawk

dialects, embodying the basic principles and the civil and political structure and organization of the League of the Iroquois and data relating thereto. The Onondaga texts aggregate about 26,955 words and the Mohawk texts about 1,480 words, making a total of 27,435 words. The following captions will indicate sufficiently the subject-matter of these texts: The Constitution of the League, the Powers of the T'hadoda'ho', Amendments, Powers and Rights of the Chiefs, Powers and Rights of the Women, Powers of the Women Chiefs, Procedure on Failure in Succession, Powers and Restrictions of "Pine Tree" Chiefs, Procedure in Case of Murder, Address of Condolence for Death in a Chief's Family, Forest-edge Chanted Address of Welcome, The Chant for the Dead, Interpretation of the Fundamental Terms, Peace, Power, and Justice.

Mr. Hewitt also continued his duties as custodian of the collection of linguistic manuscripts of the Bureau, the completion of the catalogue of which was entrusted to Mr. J. B. Clayton, head clerk. He has also been called upon to furnish data for the correspondence of the office, more particularly that part relating to the Iroquoian tribes.

Mr. F. W. Hodge, ethnologist, has been engaged during the entire year on the Handbook of American Indians, the editorial work of which has proved extremely arduous and difficult. This work is in two parts: Part I, A—M, was issued from the press in March last, and the main body of Part II was in type at the close of the fiscal year, though progress in proof reading was exceedingly slow on account of the great diversity of the topics treated and the difficulty of bringing up to date numbers of articles relating often to obscure tribes and subjects.

During the entire fiscal year Mr. James Mooney, ethnologist, remained in the office, occupied chiefly on the Handbook of American Indians and in the classification of the large body of material previously obtained relating to the tribes of the Great Plains. His extended article on Indian Missions, written for the Handbook, has been made the subject of a special reprint, a small edition of which was issued by the Bureau. Mr. Mooney has also given valuable assistance in the correspondence of the Bureau, more especially that portion relating to the languages of the Algonquian stock.

SPECIAL RESEARCHES.

For a number of years Dr. Franz Boas, assisted by a large corps of linguists, has been engaged in the preparation of a work on the American languages, to be published as a bulletin of the Bureau, entitled "Handbook of American Languages," and it is expected that the manuscript of the first part of this work will be submitted for publication at an early date. Sections relating to the languages of the Eskimo and the Iroquois alone remain incomplete. During the summer of 1906 Mr. Edward Sapir was engaged in collecting data for the handbook on the language of the Takelma tribe, located on the Siletz Agency, Oregon, and toward the close of the year Mr. Leo J. Frachtenberg began similar studies among the Tutelo remnant on the Tuscarora Reservation, Ontario, Canada.

Reports of the discovery of fossil remains of men of extremely primitive type in the vicinity of Omaha, Nebraska, led to the assignment of Dr. Aleš Hrdlička, curator of physical anthropology in the National Museum, to the duty of visiting the University of Nebraska, at Lincoln, where the remains are preserved, and also the site of their exhumation. The examinations were made with the greatest care, and the results are embodied in Bulletin 33 of the Bureau, which was in press at the close of the fiscal year. The conclusion reached by Doctor Hrdlička with respect to the age and character of these remains is that they are not geologically ancient, belonging rather to the mound-

building period in the Mississippi Valley, and that, although a number of the crania are of low type, this was a characteristic frequently appearing among comparatively recent mound-building tribes.

At the beginning of the fiscal year the Bureau was fortunate enough to enter into arrangements with Prof. Herbert E. Bolton, of the University of Texas, for recording the history of the Texan tribes. During the early historical period the French controlled and came into intimate relations with the northern Caddo, hence the early history of this group is to be found chiefly in French records; but with this exception it is mainly in Spanish records, scattered and almost wholly unprinted. These facts make the task in every sense a pioneer one.

The Spanish manuscript sources available to Professor Bolton and upon which, aside from the printed French sources, he has thus far mainly drawn, consist of (1) the Béxar archives, a rich collection of perhaps 300,000 pages of original manuscripts that accumulated at San Antonio during the Spanish occupancy, and now in the University of Texas; (2) the Nacogdoches archives, a similar but much smaller collection that accumulated at Nacogdoches and which are now in the State Historical Library; (3) the Lamar papers, a small collection of Spanish manuscripts, now in private hands; (4) mission records preserved at the residence of the Bishop of San Antonio; (5) copies of documents from the Archivo General of Mexico, belonging to the University of Texas and to Professor Bolton; and (6) the various Mexican archives. From these have been extracted a great many notes, but much material yet remains to be examined.

During the year Professor Bolton's efforts have taken three principal directions: (1) He has systematically and fully indexed, on about 10,000 cards, a large amount of the early material, including tribal, institutional, linguistic, historical, and other data on the whole Texas field. (2) From this material as a basis he has written many brief articles on tribes and missions for the Handbook of American Indians, aggregating about 20,000 words. (3) While in the analysis of the materials and the making of the index cards he has covered the whole field, in the final work of construction he has begun the Caddoan tribes of eastern Texas, with the design of treating them separately. In this work Professor Bolton has made commendable progress. He has already written a detailed description, consisting of about 40,000 words, of the location, social and political organization, economic life, religion, and ceremonial of the Hasinai, commonly designated "Texas," as known and described by the earliest European chronicles, accompanied with a map.

The task of writing a history of the Texas tribes is a great one, and can be performed only by long and painstaking effort, but its successful accomplishment promises an important addition to our knowledge of the native Americans.

PRESERVATION OF ANTIQUITIES.

With the object of assisting the departments of the Government having custody of the public domain in the initiation of measures for the preservation of the antiquities of the country, the compilation of a descriptive catalogue of antiquities has been continued, and the preparation of bulletins having the same end in view has also received every possible attention. Bulletin 32, Antiquities of the Jemez Plateau, by Edgar L. Hewett, was published and distributed during the year, and Bulletin 35, Antiquities of the Upper Gila and Salt River Valleys in Arizona and New Mexico, by Dr. Walter Hough, was in page form at the close of the year, while bulletins by Dr. J. Walter Fewkes, on the Antiquities of [illegible]ittle Colorado Valley, and Edgar L. Hewett, on the Antiquities of the [illegible]orado, were in course of preparation.

The sum of $3,000, appropriated by Congress for the excavation, repair, and preservation of Casa Grande Ruin, in Arizona, was disbursed by the Smithsonian Institution, Dr. J. Walter Fewkes, of the Bureau of American Ethnology, having charge of the work. A brief preliminary report on the first year's operations will appear in the Quarterly Issue of the Smithsonian Miscellaneous Collections. A second appropriation of $3,000 is provided for continuing the work during the coming year.

During the year uniform rules and regulations intended to serve in carrying out the recently enacted law for the preservation of national antiquities were formulated and adopted by the three departments having control of the public domain. Under these, on recommendation of the Secretary of the Smithsonian Institution, permits were issued for conducting explorations on Indian reservations and national forests in Idaho and Wyoming, by the American Museum of Natural History, New York, and among the ancient ruins on the public lands in Navaho and Apache counties, Arizona, by the University of California. Arrangements were also made with the Interior Department for carrying on explorations at Casa Grande Ruin, Arizona, by the Smithsonian Institution. Under the same law during the year three important archeological sites were declared national monuments by the President of the United States. They are as follows: Chaco Canyon, in New Mexico, including several important ruined pueblos; El Moro, New Mexico, commonly known as Inscription Rock; and Montezuma Castle, in Arizona, an important cliff ruin.

CATALOGUE OF LINGUISTIC MANUSCRIPTS.

The archives of the Bureau contain 1,626 manuscripts, mainly linguistic, of which only a partial catalogue had previously been made. In January Mr. J. B. Clayton, head clerk, began the preparation of a card catalogue, which was completed at the close of the year. The manuscripts were jacketed in manila envelopes of uniform size, except where bulk prevented, and were numbered from 1 to 1626.

The catalogue comprises about 14,000 cards which give, as completely as available data permit, the names of stock, language, dialect, collector, and locality, as well as the date of the manuscript. It was not possible in every instance to supply all the information called for under these heads, but the card has been made as complete in each case as the information permitted. The cards have been arranged in one alphabetical series, the names of the languages not only under these languages in their proper alphabetical place, but also alphabetically under their stocks. Under the name of each collector his manuscripts are indexed under stocks, languages, and dialects. The data in regard to "place" are very defective, and quite a number of the manuscripts are from anonymous sources.

EDITORIAL WORK.

Mr. Joseph G. Gurley, who was appointed to the position of editor for a probationary period during the previous year, was permanently appointed on August 16, 1906.

The editorial work of the year may be summarized briefly as follows: The proof reading of the Twenty-fourth Annual Report was completed and the work advanced to publication. At the close of the year the Twenty-fifth Annual was practically finished, with the exception of the presswork, while the Twenty-sixth Report was in page form, so that the work was practically ready for printing. Bulletin 32 was completed and published early in the year, and Bulletin 36 also has been issued. Bulletins 33, 34, and 35 are in type, and

the proof reading on Bulletins 33 and 35 has progressed so far that they can be put on the press at an early day.

For about three months the Bureau has had the efficient services of Mr. Stanley Searles, who was courteously detailed for the purpose from the proof reading force of the Government Printing Office. The editor has assisted to some extent in the proof-reading of the Handbook of American Indians, Bulletin 30, which is in charge of Mr. F. W. Hodge.

PUBLICATIONS.

During the year the Twenty-sixth Annual Report and Bulletins 33, 34, 35, and 36 were forwarded to the Public Printer. Bulletins 31 and 32 were published in July. Part I of the Handbook of American Indians (Bulletin 30) appeared in March and the Twenty-fourth Annual Report in May. One thousand copies of the List of Publications of the Bureau (Bulletin 36) and 500 copies of a special article on Indian missions were issued in June. Fifteen hundred copies of the Twenty-fourth Annual Report and the same number of Bulletin 30, Part I, and Bulletin 32 were sent to regular recipients. About 1,500 copies of Bulletin 30, Part I, and 200 copies of the Twenty-fourth Annual, as well as numerous bulletins and separates, were distributed in response to special requests, presented for the most part by Members of Congress.

The distribution of publications was continued as in former years. The great increase in the number of libraries in the country and the multiplication of demands from the public generally have resulted in the almost immediate exhaustion of the quota of volumes (3,500) allotted to the Bureau. Few copies of any of the reports remain six months after the date of issue.

LIBRARY.

The library remains in charge of Miss Ella Leary, who was able to bring the accessioning and cataloguing of books, pamphlets, and periodicals up to date. In all, there have been received and recorded during the year 760 volumes, 1,200 pamphlets, and the current issues of upward of 500 periodicals, while about 500 volumes have been bound at the Government Printing Office. The library now contains 13,657 volumes, 9,800 pamphlets, and several thousand copies of periodicals which relate to anthropology. The purchase of books and periodicals has been restricted to such as relate to anthropology and, more especially, to such as have a direct bearing on the American aborigines.

COLLECTIONS.

The collections of the year comprise large series of objects obtained by Dr. J. Walter Fewkes, in his excavations at Casa Grande Ruins, Arizona, conducted under the immediate auspices of the Smithsonian Institution, and by Mrs. M. C. Stevenson in Zuñi and Taos pueblos, New Mexico.

Some of the minor collections are a cache of stone knife blades from the vicinity of Tenleytown, District of Columbia, obtained through the kindness of Mr. C. C. Glover; a series of relics (fragments of pottery) from the temple of Diana at Caldecote, presented by Mr. Robert C. Nightingale; relics from the shell heaps of Popes Creek, Maryland, presented by Mr. S. H. Morris, of Faulk-
Maryland; and a number of stone implements and unfinished soapstone
from the ancient quarries on Connecticut avenue extended, Washington,
of Columbia, collected by Mr. W. H. Gill.

ILLUSTRATIONS.

The division of illustrations was, as heretofore, in charge of Mr. De Lancey Gill, who was assisted by Mr. Henry Walther. One hundred and fifty-nine illustrations were prepared for Bulletins 30, 33, 34, and 35, and a large number of proofs of illustrations for the various volumes were read and revised. The photographic work included the making of 277 negatives required in the illustration work and 160 portraits of Indians of visiting delegations. Negatives developed for ethnologists returning from the field numbered 96. During the year a total of 11,078 photographic prints was made.

Albert Samuel Gatschet, a distinguished philologist and ethnologist, for many years connected with the Bureau, died at his home in Washington, District of Columbia, March 16, 1907. A suitable notice of his career will be found in the Annual Report of the Bureau.

Respectfully submitted.

W. H. HOLMES, *Chief.*

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

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APPENDIX III.

REPORT ON THE INTERNATIONAL EXCHANGES.

SIR: I have the honor to submit the following report on the operations of the International Exchanges during the fiscal year ending June 30, 1907:

The Exchange Service, whose existence is almost coeval with that of the Institution, was originally designed for the purpose of exchanging Smithsonian publications for those of learned societies and universities. Through the action of Congress and a treaty negotiated with various foreign countries, to which many nations have since adhered, it has become an important international agency for the exchange of governmental, scientific, and literary publications, and is intended to benefit institutions in this country and abroad, serving as one of the most important means for carrying out a fundamental purpose of the Institution, "the diffusion of knowledge among men."

The service conducts its operations on behalf of all branches of this Government, and reciprocally receives the cooperation of most of the Departments and Bureaus at Washington. I desire, however, especially to mention the valued cooperation of the Department of State, which unfailingly, when requested, takes action, through our representatives abroad, on behalf of the service; and of the Treasury Department, which, by its instructions to collectors of customs, greatly facilitates the exchange work.

Its operations have been zealously carried on during the year by the experienced staff that has been gathered together. Details of the regular work are given below, to a considerable extent in tabular form, but before proceeding to them certain exceptional matters are briefly discussed.

The amount appropriated by Congress for the expenses of the service during the fiscal year 1907 was $28,800, and the sum collected on account of repayments during the same period was $4,568.25, making the total available resources for carrying on the system of International Exchanges $33,368.25.

The estimate submitted to Congress for conducting the service during the year 1908 was $32,200, an increase of $3,400 over the current appropriation. It is gratifying to state that this amount has been allowed.

The improvements and changes in the electric wires which furnish light for the Exchange Service, referred to in the last report, have been completed. The wires were placed in metal pipes, and the liability of fire from this source is now reduced to a minimum. The appearance of the office rooms has been much improved by the painting of the walls, woodwork, and floors, and the hanging of new shades.

When it is considered that nearly 2,000 boxes have been shipped during the year to every quarter of the globe, the statement that the service has not suffered the loss of any of its consignments is noteworthy.

A close supervision has been kept over entries of foreign consignments of books at the Georgetown custom-house and over the auction sales of all the principal ports of the United States, in order to prevent, if possible, the going astray of exchanges from abroad which are not properly addressed, and which, therefore, fail to reach the Smithsonian Institution. During the past year

these efforts have resulted in the clearing of a number of consignments for the Smithsonian Institution and the Library of Congress which might otherwise have miscarried. Whenever, during the visits to the custom-house, any exchange consignment addressed to a scientific establishment has been found unclaimed, steps have been taken to notify the proper persons regarding the matter. In such cases the sender has been informed of the channels through which exchanges should be forwarded to insure their prompt and safe delivery.

Complaints of delays in the transmission of exchanges are becoming fewer each year. Every endeavor has been made to improve the service so that the cause of complaint may be entirely eliminated, and each complaint is carefully traced in order that the cause of delay may be ascertained. It should be stated, however, that, with the exception of the countries in which the Institution has paid agents, the responsibility of the Institution for outgoing shipments necessarily ceases after they have been shipped, as the distribution in foreign countries is conducted by the government bureaus of the respective countries, over which the Smithsonian Institution, of course, has no control. In special cases, and usually upon the request of government establishments where the publications are of such a nature that their value largely depends upon the promptest possible delivery, and to addresses in countries to which shipments are very infrequent, packages are now sent by mail.

It has been the established rule to make shipments in boxes of standard size, bearing a weight of about 200 pounds each, and not to make a transmission to any country until a sufficient number of publications to fill at least one such box had accumulated. This has caused no delay in shipments to any of the larger countries, but has rendered them less frequent to those places with which the exchange is not very considerable. It is proposed during the coming year to employ smaller cases for such countries, thus making more frequent shipments possible.

Regarding the charge made by the consuls of certain South and Central American countries for certifying bills of lading, it is a pleasure to state that in nearly every instance the consuls have consented to waive such fees in the future.

Within recent years Hawaii, Porto Rico, and the Philippine Islands came under the jurisdiction of the United States. Prior to this they had been subject to foreign jurisdiction and thus came within the purview of the exchange service, but under the existing circumstances it appeared that this construction must be abandoned, and the Institution has discontinued the acceptance of packages from domestic sources for these territories, since exchanges with them no longer come within the designation "international."

Special attention continues to be given to increasing the office collection of directories and other books of addresses.

In the last report reference was made to the steps that were being taken through the Department of State to have the Government of the Argentine Republic designate one office to assume charge of the distribution of exchanges in that country, in order that the practice of sending to five different establishments might be discontinued. In response to the communication of the Department of State, the Argentine minister of foreign affairs stated that a section of exchanges was already established under the direction of the National Library of Buenos Aires, and requested that future consignments be sent in care of that library. Transmissions to Argentina have accordingly been made in this manner since January, 1907.

As was reported last year, all transmissions to Bulgaria were temporarily suspended owing to the death of Dr. Paul Leverkühn, who attended to the

distribution of exchanges in that country. It is gratifying to state that shipments have now been resumed, the Prince of Bulgaria having been good enough, in response to the request of the Institution, to designate the scientific institutions and library at Sofia to act as the exchange intermediary between Bulgaria and the United States.

The final arrangement of details concerning the shipment of Government documents to China has not been perfected, and therefore the first consignment of official publications to that country has not yet been made.

During the latter part of the present fiscal year a communication was received from Dr. F. Bonola Bey, secretary-general of the Khedivial Geographical Society in Cairo, announcing that as he was about to leave Egypt for some time he felt it would be necessary for him to give up the work which he had been conducting for the Smithsonian Institution for a number of years, and that, at his request, the director-general of the survey department at Cairo had offered to take charge of the distribution of exchanges. A letter was also received from the director-general placing the services of his department at the disposal of the Institution. Consignments will, therefore, be sent to the survey department in the future. The grateful acknowledgments of the Institution are due to Dr. Bonola Bey for the valuable services which he has rendered during the past seventeen years in the distribution of exchanges to correspondents in Egypt.

Under the arrangement which has existed for a number of years with the national library at Athens, the Smithsonian Institution has been permitted to forward to that library packages intended for distribution only to Government institutions and officials connected therewith, it being necessary to forward all other exchanges for Greece in care of the American School of Classical Studies at Athens. On account of this division of consignments it was often necessary to hold packages here for a considerable length of time before a sufficient number accumulated to constitute a shipment. The national library, however, through the good offices of Dr. Eypaldo Bassier, member of the Greek Parliament, has finally been prevailed upon to distribute exchanges for all addresses in Greece, which greatly increases the efficiency of the service between that country and the United States. In this connection it should be stated that the services which the American School of Classical Studies rendered the Institution in the distribution of exchanges for miscellaneous addresses in Greece have been eminently satisfactory, and the thanks of the Institution are due the officers of that school for their promptness in forwarding packages to their destinations.

Dr. Julius Pikler, who was temporarily appointed agent for Hungary on July 1, 1906, to fill the vacancy caused by the death of Dr. Joseph von Körösy, was, on February 7, 1907, permanently appointed.

No response has yet been received from the Korea branch of the Royal Asiatic Society at Seoul regarding the request of the Institution that the society act as the exchange medium through which packages to and from Korea may be forwarded. The Institution is, therefore, still without means of forwarding packages to Korea, transmissions to which country were suspended during the late Russo-Japanese war.

INTERCHANGE OF PUBLICATIONS BETWEEN THE UNITED STATES AND OTHER COUNTRIES.

The total number of packages handled by the International Exchange Service dur the l t year was 189,830, an increase over the number for the preceding r. The weight of these packages was 469,536 pounds, a decrease

from 1906 of 2,023 pounds. The statement which follows shows in detail the number of packages exchanged between the United States and other countries:

Statement of packages received for transmission through the International Exchange Service during the year ending June 30, 1907.

Country.	Packages.	
	For.	From.
Abyssinia	1	.....
Algeria	122	64
Angola	5	.....
Antigua	42	.....
Arabia	28	.....
Argentina	3,062	676
Austria-Hungary	6,682	3,756
Azores	29	.....
Bahamas	53	.....
Barbados	104	.....
Beira	14	.....
Belgium	3,840	2,623
Bermudas	36	.....
Bismarck Archipelago	1	.....
Bolivia	138	.....
Bombay	4	.....
Borneo	5	.....
Brazil	2,043	1,056
British America	6,110	309
British Burma	8	.....
British East Africa	15	.....
British Central Africa	4	.....
British Guiana	85	.....
British Honduras	51	.....
British West Africa	2	.....
Bulgaria	178	1
Canary Islands	17	.....
Cape Colony	1,510	23
Ceylon	220	.....
Chile	1,686	75
China	546	25
Colombia	1,161	8
Cook Islands	1	.....
Costa Rica	1,149	39
Cuba	1,152	189
Curaçao	16	.....
Cyprus	14	.....
Denmark	1,761	384
Dominica	46	.....
Dutch Guiana	39	.....
Ecuador	585	13
Egypt	335	58
Falkland Islands	15	.....
Fiji Islands	30	.....
France	12,061	4,687
French Cochin China	45	.....
German East Africa	1	.....
Germany	21,875	7,937
Gibraltar	15	.....
Gold Coast	2	.....
Grenada	13	.....
Great Britain and Ireland	20,123	7,982
Greece	1,252	.....
Greenland	2	.....
Guadeloupe	2	.....
Guatemala	218	.....
Haiti	975	.....
Hawaiian Islands	52	3
Honduras	248	.....
Hongkong	146	.....
Iceland	51	.....
India	2,580	783
Italy	6,601	2,454
Jamaica	248	.....
Japan	3,435	656
Java	252	517
Kongo	1	1
Korea	48	.....
Lagos	6	.....
Liberia	63	.....
Lourenço Marquez	82	.....
Luxemburg	98	1
Macao	1	.....
Madagascar	27	.....
Madeira	18	.....
Malta	106	.....
Martinique	15	.....
Mauritius	66	.....
Mexico	1,677	512
Mombasa	1	.....
Montenegro	3	.....
Morocco	5	.....
Natal	221	2
Netherlands	2,889	1,458
Nevis	8	.....
Newfoundland	158	.....
New South Wales	2,410	698
New Zealand	1,552	3
Nicaragua	261	.....
Norfolk Islands	13	.....
Norway	1,922	449
Orange River Colony	111	.....
Panama	424	.....
Paraguay	173	.....
Persia	51	.....
Peru	1,430	5
Philippine Islands	232	1
Porto Rico	2	.....
Portugal	1,481	104
Queensland	1,382	.....

Statement of packages received for transmission through the International Exchange Service during the year ending June 30, 1907—Continued.

Country.	Packages.		Country.	Packages.	
	For.	From.		For.	From.
Reunion	11		Spain	2,196	284
Rhodesia	47		Straits Settlements	202	
Roumania	376	134	Sudan	6	
Russia	4,842	2,594	Sumatra	3	
St. Helena	20		Sweden	2,679	1,018
St. Kitts	25		Switzerland	3,477	1,072
St. Lucia	6		Tasmania	1,129	5
St. Martin	14		Transvaal	1,176	
St. Pierre and Miquelon	17		Trinidad	94	
St. Thomas	17		Tunis	36	4
St. Vincent	2		Turkey	1,270	
Samoa	21		Turks Islands	17	
San Salvador	173		United States	43,555	146,719
Santo Domingo	35		Uruguay	1,355	90
Sarawak	3		Venezuela	1,127	
Servia	97	2	Victoria	2,824	138
Seychelles Islands	1		Western Australia	1,234	50
Siam	193		Zanzibar	15	
Sierra Leone	22		Total	189,830	189,830
Society Islands	16				
South Australia	1,418	168			

During the year there were sent abroad 1,833 boxes, 265 of which contained full sets of United States Government documents for authorized depositories, and 1,568 consisted of departmental and other publications for miscellaneous correspondents. The decrease in the number of boxes sent abroad as compared with the previous year is due, in part, to the fact that a great many more packages were forwarded directly by mail than formerly, and, in part, to the reduction in size of Government publications. The number of boxes of miscellaneous exchanges sent to each country is given below:

Argentina	20	Greece	5
Austria	64	Guatemala	4
Belgium	52	Haiti	1
Bolivia	2	Honduras	4
Brazil	19	Hungary	28
British colonies	14	India	33
British Guiana	2	Italy	78
British Honduras	1	Jamaica	3
Cape Colony	18	Japan	45
China	4	Liberia	2
Chile	11	Lourenço Marquez	2
Colombia	8	Natal	1
Costa Rica	4	New South Wales	25
Denmark	18	Netherlands	34
Ecuador	10	New Zealand	14
Egypt	7	Nicaragua	3
France and colonies	153	Norway	15
Germany	278	Panama	4
Great Britain and Ireland	308	Paraguay	2

Peru	9	Switzerland	40
Portugal	11	Syria	1
Queensland	5	Tasmania	4
Russia	65	Transvaal	4
Salvador	3	Trinidad	1
Santo Domingo	1	Turkey	3
Siam	3	Uruguay	6
South Australia	10	Venezuela	3
Spain	19	Victoria	18
Sweden	52	Western Australia	14

EXCHANGE OF GOVERNMENT DOCUMENTS.

The number of packages sent abroad through the International Exchange Service by United States Government institutions during the year was 100,114, an increase over those forwarded during the preceding twelve months of 33,086; the number received in exchange was 11,641, a decrease of 15,127. The increase in the number sent is due partly to the addition of three new depositories of partial sets of official documents and partly to the greater number of publications received from Government establishments for distribution abroad. The decrease does not signify an actual reduction in the number of publications from foreign countries, and is accounted for by the fact that all packages for the Library of Congress have, at the request of the Librarian, been delivered intact, so that, in the case of the receipts for the Library, one package sometimes represents a whole box of publications.

The exchange on account of the various branches of the Government is shown in detail in the following table:

Statement of United States Government exchanges during the year ending June 30, 1907.

Name of bureau.	Packages.		Name of bureau.	Packages.	
	Received for—	Sent by—		Received for—	Sent by—
American Historical Association	11	19	Bureau of Public Health and Marine-Hospital Service	25	1,152
Astrophysical Observatory	17	.....	Bureau of Statistics, Department of Commerce and Labor	126	6,186
Auditor for the State and other Departments	.....	361	Bureau of Steam Engineering	1	.....
Bureau of American Ethnology	275	2,107	Civil Service Commission	3	.....
Bureau of the American Republics	39	3	Coast and Geodetic Survey	169	454
Bureau of the Census	71	2,183	Commissioner of Internal Revenue	.....	17
Bureau of Education	168	43	Commissioners of the District of Columbia	9	43
Bureau of Fisheries	103	768	Comptroller of the Currency	9	140
Bureau of Immigration	.....	1	Department of Agriculture	510	262
Bureau of Insular Affairs	.....	3	Department of Commerce and Labor	5	1
Bureau of Labor	74	4,043	Department of the Interior	28	208
Bureau of Manufactures	38	6,925	Department of Justice	1	.....
Bureau of the Mint	8	404	Department of State	11	1
Bureau of Navigation, Navy Department	4	.....	Engineer School of Application	3	.....
Bureau of Navigation, Department of Commerce and Labor	.....	20			

Statement of United States Government exchanges during the year ending June 30, 1907—Continued.

Name of bureau.	Packages.		Name of bureau.	Packages.	
	Received for—	Sent by—		Received for—	Sent by—
Entomological Commission	3	.....	Navy Department	5	4
General Land Office	3	.....	Office of the Chief of Engineers	38	5
Geological Survey	723	3,261	Office of the Chief of Staff	3	21
House of Representatives	.....	1	Office of Indian Affairs	6	.....
Hydrographic Office	55	204	Ordnance Office, War Department	1	.....
Hygienic Laboratory	1	.....	Patent Office	347	1,926
Interstate Commerce Commission	26	444	Senate Library	3	.....
Library of Congress	4,009	57,727	Smithsonian Institution	3,548	7,466
Life-Saving Service	1	68	Steamboat Inspection Service	.....	1
Light-House Board	2	144	Superintendent of Documents	.....	4
National Academy of Sciences	126	57	Surgeon-General's Office	190	327
National Bureau of Standards	36	.....	Treasury Department	7	4
National Herbarium	3	.....	War Department	52	110
National Museum	403	634	Weather Bureau	120	1,439
Nautical Almanac Office	57	166	Total	11,641	100,114
Naval Observatory	165	757			

As will be seen from the foregoing statement, the number of documents sent abroad by the Departments and Bureaus of this Government is, in most instances, much greater than the quantity of similar works received in exchange. While this may partly be due to the fact that few governments publish so extensively as the United States, yet it seems unlikely that the fullest possible exchange has been attained, and it is proposed during the coming year to use a part of the increase in the exchange appropriation in the employment of an additional clerk to assist in carrying on the work of completing and increasing the number of foreign government publications received by American governmental establishments.

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENT DOCUMENTS.

In accordance with treaty stipulations and under the authority of the Congressional resolutions of March 2, 1867, and March 2, 1901, setting apart a certain number of documents for exchange with foreign countries, there are now sent regularly to depositories abroad 53 full sets of United States official publications and 30 partial sets. During the past year the Librarian of Congress, in accordance with the discretion vested in him by the act of 1901, directed that the legislative library at Edmonton, Alberta, the national library at Quito, Ecuador, and the Panama department of foreign affairs at Panama be added to the list of depositories of partial sets. The recipients of full and partial sets are as follows:

DEPOSITORIES OF FULL SETS.

Argentina: Ministerio de Relaciones Exteriores, Buenos Aires.
Argentina: Biblioteca de la Universidad Nacional de La Plata.
Australia: Library of the Commonwealth Parliament, Melbourne.

Austria: K. K. Statistische Central-Commission, Vienna.
Baden: Universitäts-Bibliothek, Freiburg.
Bavaria: Königliche Hof- und Staats-Bibliothek, Munich.
Belgium: Bibliothèque Royale, Brussels.
Brazil: Bibliotheca Nacional, Rio de Janeiro.
Canada: Parliamentary Library, Ottawa.
Cape Colony: Government Stationery Department, Cape Town.
Chile: Biblioteca del Congreso Nacional, Santiago.
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito y Canje de Publicaciones, San José.
Cuba: Department of State, Habana.
Denmark: Kongelige Bibliotheket, Copenhagen.
England: British Museum, London.
England: London School of Economics and Political Science, London.
France: Bibliothèque Nationale, Paris.
France: Préfecture de la Seine, Paris.
Germany: Deutsche Reichstags-Bibliothek, Berlin.
Greece: National Library, Athens.
Haiti: Secrétairerie d'État des Relations Extérieures, Port-au-Prince.
Hungary: Hungarian House of Delegates, Budapest.
India: Home Department, Government of India, Calcutta.
Ireland: National Library of Ireland, Dublin.
Italy: Biblioteca Nazionale Vittorio Emanuele, Rome.
Japan: Department of Foreign Affairs, Tokyo.
Manitoba: Provincial Library, Winnipeg.
Mexico: Instituto Bibliográfico, Biblioteca Nacional, Mexico.
Netherlands: Library of the States General, The Hague.
New South Wales: Board for International Exchanges, Sydney.
New Zealand: General Assembly Library, Wellington.
Norway: Storthingets Bibliothek, Christiania.
Ontario: Legislative Library, Toronto.
Peru: Biblioteca Nacional, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Prussia: Königliche Bibliothek, Berlin.
Quebec: Legislative Library, Quebec.
Queensland: Parliamentary Library, Brisbane.
Russia: Imperial Public Library, St. Petersburg.
Saxony: Königliche Oeffentliche Bibliothek, Dresden.
South Australia: Parliamentary Library, Adelaide.
Spain: Depósito de Libros, Cambio Internacional y Biblioteca General del Ministerio de Instrucción Pública y Bellas Artes, Madrid.
Sweden: Kongliga Biblioteket, Stockholm.
Switzerland: Bibliothèque Fédérale, Berne.
Tasmania: Parliamentary Library, Hobart.
Transvaal: Government Library, Pretoria.
Turkey: Department of Public Instruction, Constantinople.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional de Publicaciones, Montevideo.
Venezuela: Biblioteca Nacional, Carácas.
Victoria: Public Library, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Württemberg: Königliche Landesbibliothek, Stuttgart.

DEPOSITORIES OF PARTIAL SETS.

Alberta: Legislative Library, Edmonton.
Austria-Hungary: Bürgermeister der Haupt- und Residenz-Stadt, Vienna.
Bolivia: United States Minister, La Paz.
British Columbia: Legislative Library, Victoria.
Bulgaria: Minister of Foreign Affairs, Sofia.
Ceylon: United States Consul, Colombo.
Ecuador: Biblioteca Nacional, Quito.
Egypt: Bibliothèque Khédiviale, Cairo.
Germany: Grossherzogliche Hof-Bibliothek, Darmstadt.
Germany: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten, Hamburg.
Germany: Kommission für Reichs- und Auswärtige Angelegenheiten, Bremen.
Guatemala: Secretary of the Government, Guatemala.
Honduras: Secretary of the Government, Tegucigalpa.
Jamaica: Colonial Secretary, Kingston.
Lourenço Marquez: Government Library, Lourenço Marquez.
Malta: Lieutenant-Governor, Valetta.
Newfoundland: Colonial Secretary, St. Johns.
New Brunswick: Legislative Library, St. John.
Natal: Colonial Governor, Pietermaritzburg.
Nicaragua: Superintendente de Archivos Nacionales, Managua.
Nova Scotia: Legislative Library, Halifax.
Northwest Territories: Government Library, Regina.
Orange River Colony: Government Library, Bloemfontein.
Panama: Secretaria de Relaciones Exteriores, Panama.
Prince Edward Island: Legislative Library, Charlottetown.
Paraguay: Oficina General de Informaciones y Canjes y Commisaria General de Inmigracion, Asuncion.
Roumania: Academia Romana, Bukharest.
Salvador: Ministerio de Relaciones Exteriores, San Salvador.
Straits Settlements: Colonial Secretary, Singapore.
Siam: Department of Foreign Affairs, Bangkok.

CORRESPONDENTS.

The record of exchange correspondents at the close of the year contained 58,107 addresses, being an increase of 1,793 over the preceding year. The following table gives the number of correspondents in each country, and also serves to illustrate the scope of the service, whose utility is becoming every year better and more widely appreciated.

Number of correspondents of the International Exchange Service in each country on June 30, 1907.

Country.	Correspondents.		
	Libraries.	Individuals.	Total.
AFRICA.			
Algeria	27	55	82
Angola	1	2	3
Azores	7	15	22
Beira	.....	1	1
British Central Africa	1	3	4
British East Africa	1	4	5
Canary Islands	2	8	10
Cape Colony	69	127	196
Cape Verde Islands	.....	5	5
Egypt	52	109	161
French Kongo	.....	2	2
Gambia	.....	1	1
German East Africa	5	.....	5
Gold Coast	1	4	5
Kongo	.....	5	5
Lagos	3	6	9
Liberia	3	12	15
Lourenço Marquez	1	6	7
Madagascar	6	11	17
Madeira	3	4	7
Mauritius	11	13	24
Morocco	.....	15	15
Mozambique	.....	1	1
Natal	24	35	59
Orange River Colony	3	6	9
Reunion	4	2	9
Rhodesia	11	17	28
St. Helena	3	2	5
Senegal	1	5	6
Sierra Leone	2	6	8
Southern Nigeria	1	.....	1
Sudan	2	4	6
Transvaal Colony	38	69	107
Tunis	9	12	21
Zanzibar	2	5	7
AMERICA (NORTH).			
Canada	405	734	1,139
Central America:			
British Honduras	6	18	24
Costa Rica	29	56	85
Guatemala	44	76	120
Honduras	15	46	61
Nicaragua	20	56	76
Salvador	22	16	38
Greenland	3	.....	3
Mexico	181	275	456
Newfoundland	18	40	58
St. Pierre-Miquelon	2	2	4
United States of America	3,843	7,750	11,593

Country.	Correspondents.		
	Libraries.	Individuals.	Total.
AMERICA (NORTH)—continued.			
West Indies:			
Anguilla	.....	1	1
Antigua	9	8	17
Bahamas	4	17	21
Barbados	12	28	40
Bermuda	6	29	35
Bonaire	.....	1	1
Cuba	84	150	234
Curaçao	3	7	10
Dominica	2	8	10
Green Turtle Cay	.....	1	1
Grenada	3	6	9
Guadeloupe	2	7	9
Haiti	38	23	61
Jamaica	20	51	71
Martinique	.....	3	3
Montserrat	.....	3	3
Nevis	.....	1	1
Porto Rico	11	36	47
St. Bartholomew	.....	2	2
St. Christopher	2	9	11
St. Croix	1	4	5
St. Eustatius	.....	1	1
St. Lucia	3	6	9
St. Martin	.....	2	2
St. Thomas	2	5	7
St. Vincent	1	2	3
San Domingo	5	16	21
Tobago	.....	2	2
Trinidad	17	17	34
Turks Islands	3	6	9
Virgin Islands	.....	1	1
AMERICA (SOUTH).			
Argentina	171	297	468
Bolivia	24	22	46
Brazil	165	240	405
British Guiana	20	17	37
Chile	104	144	248
Colombia	40	66	106
Dutch Guiana	6	4	10
Ecuador	27	35	62
Falkland Islands	.....	8	8
French Guiana	1	2	3
Panama	5	25	30
Paraguay	22	16	38
Peru	57	113	170
Uruguay	57	48	105
Venezuela	43	69	112

***Number of correspondents of the International Exchange Service in each country on June 30, 1907*—Continued.**

Country.	Correspondents.		
	Libraries.	Individuals.	Total.
ASIA.			
Arabia	.....	7	7
Baluchistan	.....	1	1
Burma	14	8	22
Ceylon	33	30	63
China	63	164	227
Cyprus	4	4	8
French India	1	1	2
Hongkong	14	41	55
India	329	385	714
Indo-China	10	14	24
Japan	224	574	798
Korea	5	15	20
Macao	1	1	2
Malaysia:			
Borneo	.....	1	1
British New Guinea	.....	2	2
British North Borneo	1	2	3
Celebes	.....	3	3
Java	24	43	67
New Guinea	.....	4	4
Philippine Islands	27	.....	27
Sarawak	1	.....	1
Sumatra	1	13	14
Persia	4	11	15
Portuguese India	1	.....	1
Siam	9	29	38
Straits Settlements	22	31	53
AUSTRALASIA.			
New South Wales	95	225	320
New Zealand	101	185	286
Queensland	59	77	136
South Australia	46	94	140
Tasmania	28	37	65
Victoria	137	309	446
Western Australia	38	55	93
EUROPE.			
Austria-Hungary	846	1,575	2,421
Belgium	429	630	1,059
Bulgaria	17	25	42
Denmark	127	292	419
France	1,968	3,836	5,804
Germany	2,774	5,818	8,592
Gibraltar	1	7	8
Great Britain	2,454	7,520	9,974
Greece	45	71	116
Iceland	26	14	40
Italy	957	1,462	2,419
Luxemburg	14	10	24
Malta	13	16	29
Montenegro	3	1	4
Netherlands	248	489	737
Norway	151	255	406
Portugal	118	118	236
Roumania	47	91	138
Russia	637	1,283	1,920
Servia	22	18	40
Spain	230	359	589
Sweden	209	520	729
Switzerland	418	873	1,291
Turkey	56	119	175
POLYNESIA.			
Fiji Islands	2	.....	2
German New Guinea	1	.....	1
Guam	.....	1	1
Hawaii	30	82	112
Marshall Islands	.....	5	5
New Caledonia	.....	2	2
New Hebrides	1	.....	1
Samoa	1	5	6
Seychelles Islands	.....	1	1
Tahiti	.....	9	9
Tonga	.....	3	3
International	43	.....	43
Total	19,031	39,076	58,107

Following is a list of bureaus or agencies through which the distribution of exchanges is effected. Those in the larger countries and in many of the smaller ones forward to the Smithsonian Institution reciprocal contributions for distribution in the United States:

LIST OF BUREAUS OR AGENCIES THROUGH WHICH EXCHANGES ARE TRANSMITTED.

Algeria: Via France.
Angola: Via Portugal.
Argentina: Seccion de Depósito, Reparto y Canje de Publicaciones, Biblioteca Nacional, Buenos Aires.
Austria: K. K. Statistische Central-Commission, Vienna.
Azores: Via Portugal.
Barbados: Imperial Department of Agriculture, Bridgetown.
Belgium: Service Belge des Échanges Internationaux, Brussels.
Bermuda: Sent by mail.
Bolivia: Oficina Nacional de Inmigración, Estadística y Propaganda Geográfica.
Brazil: Serviço de Permulaçõs Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
British colonies: Crown Agents for the Colonies, London.[a]
British Guiana: Royal Agricultural and Commercial Society, Georgetown.
British Honduras: Colonial Secretary, Belize.
Bulgaria: Institutions et Bibliothèque scientifiques de S. A. R. le Prince de Bulgarie, Sofia.
Canada: Sent by mail.
Canary Islands: Via Spain.
Cape Colony: Government Stationery Department, Cape Town.
Chile: Universidad de Chile, Santiago.
China: Zi-ka-wei Observatory, Shanghai.
Colombia: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito y Canje de Publicaciones, San José.
Cuba: Sent by mail.
Denmark: Kongelige Danske Videnskabernes Selskab, Copenhagen.
Dutch Guiana: Surinaamsche Koloniale Bibliotheek, Paramaribo.
Ecuador: Ministerio de Relaciones Exteriores, Quito.
Egypt: Director-General, Survey Department, Cairo.
France: Service des Echanges Internationaux, Paris.
Friendly Islands: Sent by mail.
Germany: Karl W. Hiersemann, Königsstrasse 3, Leipzig.
Great Britain and Ireland: Messrs. William Wesley & Son, 28 Essex street, Strand, London.
Greece: Bibliothèque Nationale, Athens.
Greenland: Via Denmark.
Guadeloupe: Via France.
Guatemala: Instituto Nacional de Guatemala, Guatemala.
Guinea: Via Portugal.
Haiti: Secrétairerie d'État des Relations Extérieures, Port au Prince.
Honduras: Biblioteca Nacional, Tegucigalpa.

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[a] This method is employed for communicating with a large number of the British colonies with which no route is available for forwarding exchanges direct.

Hungary: Dr. Julius Pikler, Municipal Office of Statistics, City Hall, Budapest
Iceland: Via Denmark.
India: India Store Department, London.
Italy: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.
Jamaica: Institute of Jamaica, Kingston.
Japan: Department of Foreign Affairs, Tokyo.
Java: Via Netherlands.
Korea: Shipments temporarily suspended.
Liberia: Care of American Colonization Society, Washington, D. C.
Lourenço Marquez: Government Library, Lourenço Marquez.
Luxemburg: Via Germany.
Madagascar: Via France.
Madeira: Via Portugal.
Mexico: Sent by mail.
Mozambique: Via Portugal.
Natal: Agent-General for Natal, London.
Netherlands: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Université, Leyden.
Newfoundland: Sent by mail.
New Guinea: Via Netherlands.
New Hebrides: Sent by mail.
New South Wales: Board for International Exchanges, Sydney.
New Zealand: Colonial Museum, Wellington.
Nicaragua: Ministerio de Relaciones Exteriores, Managua.
Norway: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.
Paraguay: Ministerio de Relaciones Exteriores, Asuncion.
Persia: Board of Foreign Missions of the Presbyterian Church, New York City.
Peru: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Queensland: Board of Exchanges of International Publications, Brisbane.
Roumania: Via Germany.
Russia: Commission Russe des Échanges Internationaux, Bibliothèque Impériale Publique, St. Petersburg.
St. Christopher: Sent by mail.
Salvador: Museo Nacional, San Salvador.
Santo Domingo: Sent by mail.
Servia: Via Germany.
Siam: Department of Foreign Affairs, Bangkok.
South Australia: Public Library of South Australia, Adelaide.
Spain: Depósito de Libros, Cambio Internacional y Biblioteca General del Ministerio de Instrucción Pública y Bellas Artes, Madrid.
Sumatra: Via Netherlands.
Sweden: Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Service des Échanges Internationaux, Bibliothèque Fédérale Centrale, Berne.
Syria: Board of Foreign Missions of the Presbyterian Church, New York.
Tasmania: Royal Society of Tasmania, Hobart.
Transvaal: Government Library, Pretoria.
Trinidad: Victoria Institute, Port of Spain.
[illegible]s: Via France.
[illegible]ey: American Board of Commissioners for Foreign Missions, Boston.
[illegible]: Oficina de Depósito, Reparto y Canje Internacional, Montevideo.

Venezuela: Biblioteca Nacional, Caracas.
Victoria: Public Library of Victoria, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Zanzibar: Sent by mail.

The earthquake in San Francisco in April, 1906, and the great fire which followed destroyed the buildings of the California Academy of Sciences, together with their entire contents. The Smithsonian Institution has in various ways been aiding the Academy in the rehabilitation of its library and collections. As a part of this general effort the International Exchange Service sent a circular to the foreign correspondents of the Academy soliciting contributions, and to this a most liberal response has been received, aggregating in all 6,370 packages of publications, which have been received from abroad and forwarded from Washington to San Francisco. All the correspondents of the Academy have not yet responded to the circular from the Institution, and it is anticipated that still further contributions will be received. It may be added that this is the first time since its organization that the Exchange Service has sent out a circular of this character in behalf of any establishment. The foregoing remarks refer only to the foreign part of the work, which the Smithsonian Institution has undertaken in behalf of the California Academy of Sciences, the domestic part being attended to by the institution proper.

Mr. F. V. Berry, who has been connected with the service nearly a quarter of a century, and has been acting chief clerk of the International Exchanges since the transfer of Mr. W. I. Adams to the position of disbursing agent of the Smithsonian Institution in 1905, was in recognition of his faithful and capable services appointed to the post of chief clerk, to take effect July 1, 1907. Mr. Adams, whose experience in the office and knowledge of conditions abroad are most helpful, will continue to give his advice and cooperation.

In conclusion, mention should be made of the valuable services which are rendered the Institution by those correspondents abroad who give their personal attention and doubtless often expend private means in furthering the interests of the international exchange service. The thanks of the Smithsonian Institution are also due Mr. Charles A. King, deputy collector of customs at the port of New York, for his constant assistance in clearing exchange consignments from abroad.

Respectfully submitted.

CYRUS ADLER,
Assistant Secretary, in Charge of Library and Exchanges.

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

APPENDIX IV.

REPORT ON THE NATIONAL ZOOLOGICAL PARK.

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1907:

The amount appropriated by Congress for the park during the year amounted to $95,000, and at the beginning of the year there was prepared the following scheme of operations:

Regular maintenance expenses	$78,630
Collecting, purchase, and transportation of animals	4,600
Work on small mammal house	3,000
Work on heating plant	1,000
Repairs to animal inclosures	1,500
Repairs to aquarium	300
Repairs to shop building	270
Planting shade trees and shrubs	500
Provisionally assigned to laboratory and hospital	5,200
Total	95,000

The expenditures for the year practically followed this scheme, excepting in the case of the amount reserved for a laboratory and hospital building. Conditions that arose made it necessary to apply this sum as follows:

Bear yards	$2,400
Repairing Adams Mill road	1,100
Survey of park	645
Purchase of animals	500
New roof on llama house	280
Painting flying cage	150
Repairing office	125
Total	5,200

HOUSE FOR SMALL MAMMALS.

The small mammal house which has been under construction for several years was finally opened to the public on November 15. It is found to be much the most satisfactory of the buildings erected at the park, being easily warmed, quite sanitary, and free from drafts. The method of lighting is unusual, there being skylights formed of glass tile in the roof which admit light directly over the cages, the central corridor in which the public are admitted being lighted indirectly. Screens of ribbed glass protect the animals from the cold air which descends from the roof. The cages are readily ventilated by tilting these screens. A plan of this building was published in the report of 1904.

The outside cages required for this house were not wholly completed at the end of the year, owing to the difficulty of obtaining some of the necessary material. Work upon them was, however, well advanced.

As there has always been great difficulty in keeping the monkeys at the park in a proper condition of health, it was decided to transfer all specimens of quadrumana to this building and to add such others as would serve to represent the order. Funds were lacking for purchasing any of the larger or anthropold apes, but there is a fair collection of specimens of both New World and Old World monkeys, which attracts great attention, and is appreciated by the public.

The grounds about the building have been graded, improved, and planted, and contracts let for a concrete walk along two sides.

ADDITIONAL BEAR YARDS.

Contracts were made for the floors and steel work of two additional yards in the series already begun. These yards will each have a width of 40 feet at the front and a depth of 32 to 40 feet. They will be similar in all respects to those already built, now occupied by polar bears and Alaskan brown bears.

A concrete walk, with a width of 12 feet, will be constructed at the same time that the pavement is put in for the yards.

IMPORTANT REPAIR WORK.

The flying cage was repainted throughout, a new roof was put on the llama house, the aquarium roof was repaired, new supports put in for the tanks, and other necessary repairs made; the temporary building used for blacksmith and carpenter shop and in which also the boilers of the central heating plant are located was repaired and the walls ceiled on the inside, so that the building might be kept at a reasonably warm temperature during the winter.

Several of the old outdoor cages, which had become unsafe through decay, were replaced by new ones. A considerable part of the wire fencing around the American bison paddock had to be renewed and a large amount of other fence repairs had to be made. The deer shed, which was so badly weakened by decay that it was no longer safe, was removed. The site of this shed in the hillside near the creek was so damp that it was found to be unhealthy for the animals.

ADAMS MILL ROAD.

Heavy, torrential rains almost completely denuded of surface layer the steep portion of this road, about 1,700 feet in length, and the larger stone became so loosened that the road was hardly safe for use. As this is one of the principal driveways of the District, much used for pleasure driving, it was considered imperative that it should be put in a safe condition at once. It was thoroughly overhauled and resurfaced during the autumn of 1906.

A new walk was built to connect the log bridge, by way of a picturesque ravine, with the more important animal buildings. A rock work was built with bowlders at the head of the ravine and the waste water from the aquarium tanks and hydraulic pump carried there to form a cascade.

PLANTING.

Planting was carried on at suitable times throughout the year, as far as available funds permitted. The whole park should be carefully gone over and the forest be properly thinned so that the trees can have an opportunity to develop. At present much of it is too thickly wooded.

CENTRAL HEATING PLANT.

The central heating plant which had been installed during the previous year was operated throughout the winter of 1906–7 and five of the more important buildings were heated from it. Steam is used for the present, as there was not a sufficient amount available for the plant to put in a hot-water system with forced circulation. All mains, however, are of suitable size for hot water and it is expected that it will ultimately be converted into a hot-water system. It has worked very satisfactorily and there has been practically no loss of heat from the outdoor conduits. The buildings formerly heated by individual boilers, and now supplied from the central heating plant, are free from dirt and dust, and the new arrangement is in every way a great improvement. Thanks are due to the Supervising Architect for advice and assistance and for detailing an expert heating engineer to plan and supervise this work.

SURVEY OF THE PARK.

The detailed topographic survey of the park, which was carried on in 1904–5 and 1905–6, was finally completed during this year, about 107½ acres being carefully plotted. This survey extends to the line of the new highways on the southeastern and western sides of the park. The resulting map is on a scale of 50 feet to the inch and shows contours at elevations of 2 feet, also all prominent objects and the underground drains and water pipes.

ACCESSIONS AND LOSSES.

Gifts.—The following animals were received by gift:

From E. H. Plumacher, United States consul, Maracaibo, Venezuela, 1 capybara, 1 crab-eating dog, 1 king vulture, 1 macaw.

From C. H. Jones, Campeche, Mexico, 2 ocelots, 6 Mexican curassows, 1 Chapman's curassow, 3 chachalacas.

From O. J. Field, chief clerk, Department of Justice, 1 cinnamon bear.

From Victor J. Evans, Washington, District of Columbia, 2 mangabey monkeys.

From Mrs. Geo. R. Shanton, Ancon, Canal Zone, Panama, 2 Panama curassows.

Exchanges.—The more important animals secured in this manner during the year were: One leucoryx, from the New York Zoological Park; 2 American marten; 1 victoria crowned pigeon.

Purchases.—Among the purchases were the following: Two American bison, 2 South American jaguars, 1 Mexican jaguar, 1 tigress, 1 black leopard, 1 pair of ocellated turkeys, 1 pair of California sea lions.

Births.—Among the births were: Two American bison, 6 American elk, 3 mule deer, 1 Barasingha deer, 2 red deer, 1 Cuban deer, 3 Barbary sheep, 1 llama, 3 peccaries, and 11 wild turkeys, besides a number of species of heron, ibis, cormorant, etc., nested in the flying cage.

Important deaths.—The more important deaths were as follows:

Young lion presented to the President by the King of Abyssinia, from chronic arthritis.

Black bear, from an extreme case of infestation with Ascaris transfugæ; the duodenum was perforated in several places.

Bactrian camel, female, from peritonitis and secondary pneumonia.

Llama, male, from pneumonia.

Moose, from catarrhal enteritis and fatty degeneration of liver.

Great gray kangaroo, from pulmonary tuberculosis.

Fifteen blue foxes, most of them from nephritis and fatty degeneration of liver, although the pathologists have not been able to ascertain the cause of this condition.

California condor, from gastro-enteritis.

The deaths also included 1 mule deer, 2 beavers, 1 Columbian black-tailed deer, 1 tahr, 1 markhor, 1 young tapir, a number of monkeys (mostly those recently received from dealers), and 1 ocellated turkey, just received.

Gastro-enteritis was still the most frequent cause of death, and pneumonia second, except with the newly received monkeys, several of which died from tuberculosis.

Statement of animal collection.

Accessions during the year:

Presented	64
Loaned	15
Purchased and collected	179
Received in exchange	6
Born in National Zoological Park	78
Captured in National Zoological Park	1
Total	343

There was considerable loss of birds during the year, especially among the smaller species. Several hundred birds which had been procured for the exhibit of the park at the Louisiana Purchase Exposition were brought to Washington at its close, and they added materially to the interest and attractiveness of the collection here. The only place available for them during winter, however, has been the temporary bird house, where the cage accommodations have been altogether inadequate. The loss has not been greater than must be expected under such conditions, but has reduced the number of birds in the collection by about 100, as it did not seem advisable to replace these birds until permanent and suitable accommodations could be provided. The number of mammals in the collection is slightly greater than at the close of the previous year, while the number of reptiles remains practically unchanged.

Animals presented during the fiscal year ending June 30, 1907.

Name.	Donor.	Number.
Sooty mangabey	Victor J. Evans, Washington, District of Columbia	2
Common macaque	Capt. J. L. Brooks, United States Army	1
White-throated capuchin	Lieut. R. Y. Rhea, United States Marine Corps	1
"Weeper" capuchin	Mr. Lutz, Washington, District of Columbia	1
Ocelot	Charles H. Jones, Campeche, Mexico	2
Crab-eating dog	Hon. E. H. Plumacher, American consul, Maracaibo, Venezuela.	1
Red fox	H. S. Knight, Takoma Park, District of Columbia	1
Do	H. D. Hughes, Washington, District of Columbia	1
Black bear	Robert Allen, Washington, District of Columbia	1
Cinnamon bear	O. J. Field, Washington, District of Columbia	1
Bactrian camel	Barnum & Bailey Shows, Bridgeport, Connecticut	1
Thirteen-lined spermophile.	Donor unknown	1
Prairie dog	Dr. L. Wilson, Washington, District of Columbia	5
Woodchuck	W. E. Calladay, Stoughton, Wisconsin	2
Capybara	Hon. E. H. Plumacher, American consul, Maracaibo, Venezuela.	1
Wax-bill finch	Miss Foster, Washington, District of Columbia	2
Java sparrow	Dr. M. F. Thompson, Washington, District of Columbia	1
Do	F. W. Jackson, Washington, District of Columbia	1
Canary	Capt. W. W. Somerville, Washington, District of Columbia	1
Do	Mrs. Price, Washington, District of Columbia	1
Red and blue macaw	Hon. E. H. Plumacher, American consul, Maracaibo, Venezuela.	1
Amazon parrot	Henry Seymour, Washington, District of Columbia	1
Lory	Mrs. Guy Norman, Washington, District of Columbia	2
Barred owl	D. W. Adams, Herndon, Virginia	1
Do	Dr. C. B. Robinson, Washington, District of Columbia	1
Barn owl	Sexton, Church of the Ascension, Washington, District of Columbia.	1
Sparrow hawk	Donor unknown	1
Do	Wm. Lawrence Tanner, Washington, District of Columbia	2
Swainson's hawk	Master Howard Maurin, jr., Washington, District of Columbia.	2
Turkey vulture	Jesse Hand, jr., Belleplain, New Jersey	1
King vulture	Hon. E. H. Plumacher, American consul, Maracaibo, Venezuela.	1
Ring dove	Dr. J. R. Spangler, York, Pennsylvania	3
Chachalaca	Charles H. Jones, Campeche, Mexico	3
Mexican curassow	do	6
Chapman's curassow	do	1
Panama curassow	Mrs. G. R. Shanton, Ancon, Canal Zone, Panama	2
Ocellated turkey	Charles H. Jones, Campeche, Mexico	1
American bittern	Miss Brewster, Washington, District of Columbia	1
Alligator	Miss Stephenson, Washington, District of Columbia	1
Diamond rattlesnake (with 13 young).	Dr. E. H. Sellards, Gainesville, Florida	1
Copperhead	D. B. Wheeler, Washington, District of Columbia	1
Emperor boa	W. B. Honey, Culebra, Canal Zone, Panama	1
Hog-nosed snake	Donor unknown	1

SUMMARY.

Animals on hand July 1, 1906	1,272
Accessions during the year	343
Total	1,615
Deduct loss (by exchange, death, and returning of animals)	422
On hand June 30, 1907	1,193

Respectfully submitted.

FRANK BAKER,
Superintendent.

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

APPENDIX V.

REPORT ON THE ASTROPHYSICAL OBSERVATORY.

SIR: I have the honor to present the following report on the operations of the Astrophysical Observatory during the fiscal year ending June 30, 1907:

During the past year the cost of the necessary repairs and repainting of the Observatory inclosure and buildings has been $300. Plans have been prepared and contracts awarded, incurring a total liability of $2,000, for the installation of electric lighting, power, and laboratory service currents, to replace the present inadequate facilities. These improvements are not as yet completed.

Apparatus for research has been procured at a cost of $600.

The usual scientific periodicals have been continued, and books of reference purchased at a total cost to the Observatory of $600.

No losses of property have occurred.

Personnel.—C. G. Abbot was promoted to be acting director July 1, 1906, and Director March 1, 1907.

F. E. Fowle was promoted to be aid March 1, 1907.

J. C. Dwyer was promoted to be messenger March 1, 1907.

L. R. Ingersoll served as temporary bolometric assistant from July 1 to September 10, 1906.

Miss C. V. Barber served as temporary computer January 2 to June 25, 1907.

P. R. Tavenner, fireman, was transferred to the Department of Agriculture June 15, 1907.

WORK OF THE OBSERVATORY.

The work of the Observatory has consisted as follows:

1. Observations at Mount Wilson and Washington.
2. Preparation of Volume II of the Observatory Annals.

OBSERVATIONS AT MOUNT WILSON.

The staff of the Mount Wilson expedition, mentioned in last year's report, continued observations for determining the "solar constant" of radiation until October 22, 1906, when the apparatus was packed and in part returned to Washington. During the stay of the expedition in 1906 about seventy days were devoted to "solar constant" observations, and with generally excellent results.

Much attention was paid to the observation of the intensity of light reflected from clouds, with a view to the determination of the albedo, or total reflection of the earth. The quality and amount of light of the sky was also measured on several days. Very successful trials were made with the continuously recording standard pyrheliometer mentioned in former reports, and the other instruments used on Mount Wilson were compared carefully with each other and with it. From these comparisons, made on different days and with widely differing conditions, it appears that the scale of values heretofore employed in the reduction of Mount Wilson observations is probably 1.5 per cent too high. But it has been decided not to make a correction for this until the completion and trial of a new continuously recording pyrheliometer, now partly done, of different dimensions and improved construction.

OBSERVATIONS AT WASHINGTON.

Measurements for the determination of the "solar constant" of radiation were made whenever the atmospheric conditions permitted. These occasions are too infrequent to permit us to make at Washington a full record of the condition of the sun, but in connection with and supplementary to the Mount Wilson work, the Washington results are of very great value.

Measurements have been made frequently of the distribution of brightness over the solar disk, and the results of these measurements indicate, though perhaps not conclusively, that when the contrast in brightness between the center and edge of the solar disk is greater than usual, the intensity of solar radiation available to warm the earth is less than usual, and vice versa. This relation was suspected in former years.

PREPARATION OF VOLUME II OF THE OBSERVATORY ANNALS.

The reduction and preparation for publication of the results of the thousands of bolographic records made in the research on solar radiation has involved measurements and computations requiring the recording of upward of 2,000,000 separate figures. The reductions have been chiefly in the care of Mr. Fowle, and he has been ably seconded by Miss Graves. Very useful and painstaking assistance has been rendered by Mr. Dwyer and by the temporary computers employed. The text and illustrations have been prepared under the care of the writer, in consultation with Mr. Fowle. The whole work was nearly completed at the conclusion of the fiscal year, and at this writing (September 15) is now ready for the press. As the story of the year's work is chiefly the story of this volume, it will not be out of place to give here a summary of its principal contents.

SUMMARY OF THE FORTHCOMING VOLUME OF ANNALS.

The present volume is an account of the work of the Astrophysical Observatory from 1900 to 1907, with details of the investigations made, the apparatus and methods used, and the results obtained.

Speaking broadly, the investigation relates to the intensity of the rays of the sun, and the dependence of the earth's temperature thereon. The subject is here treated in three parts: First, the amount of the solar radiation as it would be found if measured outside the earth's atmosphere, at mean solar distance, or, as it is often termed, "The solar constant of radiation." Second, the dependence of the earth's temperature on the amount of solar radiation. Third, the difference in brightness between the center and edge of the sun's disk and its relation to the quantity of solar radiation received by the earth.

The work is not limited to a determination of constants of nature, for the possibility was early recognized that the radiation of the sun might be far from uniform, so that the "solar constant of radiation" might prove to be a mean value about which the intensity of the solar beam would be found to fluctuate very perceptibly from time to time. A principal aim of the work has therefore been to prove whether such fluctuations of the quantity of solar rays do exist, and, if so, what may be the magnitude of the changes, their effects on climate, and their causes. For these purposes the measurement of the intensity of solar radiation and of the distribution of brightness over the disk of the sun have been made as often as possible for several years, and a study of the variation of temperature for the last thirty years at about fifty stations scattered as widely as possible over the inland areas of the world has also been made.

A part of the measurements have been made in Washington, and therefore practically at sea level, and a part at Mount Wilson, in California, at about 1,800 meters, or nearly 6,000 feet elevation. The radiation of the sun has been studied, not only in the total, but also as dispersed into its spectrum, and not only in the part visible to the eye, but also in those portions whose wave lengths are too long or too short to affect the eye. For all these different rays the earth's atmosphere produces different degrees of absorption, or of diffuse reflection, and in the course of the work the transparency of the earth's atmosphere for many different rays has been extensively investigated. The reflecting powers of the clouds and the air have been measured, and also the quality of the sky light as regards the relative intensity of its rays of different colors.

We use as our unit of measurement that intensity of radiation which, when fully absorbed for one minute over a square centimeter of area, placed at right angles to the ray, would produce heat enough to raise the temperature of a gram of water 1° centigrade. This unit is termed 1 calorie per square centimeter per minute.[a]

The mean result of 130 measurements conducted on Mount Wilson in the summer and autumn months of 1905 and 1906 fixes the intensity of solar radiation outside the atmosphere at mean solar distance as 2.023 calories per square centimeter per minute.

The mean result of 41 measurements at Washington from 1902 to 1907 is 2.061 calories.

It is probable that the mean result of such measurements, if conducted for a long term of years, would be higher, and the probable mean value of the solar constant may be estimated in round numbers at 2.1 calories per square centimeter per minute.

Expressed in another way, the solar radiation is capable of melting an ice-shell, 35 meters (114 feet) thick, annually over the whole surface of the earth.

The results of Langley, while seemingly in contradiction of these, in reality support them. For, as he states on page 211 of the Report of the Mount Whitney expedition, his value (3 calories) for the "solar constant" depends upon an allowance which he made for an apparent "systematic error in high and low sun observations at one station," of such a nature as becomes manifest "by calculating at the lower station, from our high and low sun observations there, the heat which should be found at a certain height in the atmosphere, then actually ascending to this height, and finding the observed heat there conspicuously and systematically greater than the calculated one." As shown in Chapter VII, Part I, of the present volume, this seeming discrepancy arose from a misapprehension of the requirements of the calculations. In fact, there is no such systematic error, no correction for it should have been applied by Langley, and the best mean value of his experimental determination of the "solar constant" at Mount Whitney and Lone Pine is 2.14 calories per square centimeter per minute.

Substantial agreement as to the magnitude of the "solar constant" is therefore reached by observations at sea level, at 1,800 meters, and at 3,500 meters elevation.

The solar radiation is far from being constant in its intensity. The values determined on Mount Wilson range from 1.93 calories to 2.14 calories, and those in Washington from 1.89 calories to 2.22 calories. A change of the intensity of solar radiation of 3½ per cent, due to the decrease in solar distance, occurs from August to October, and this is readily discernible in the work done

[a]As above stated, it is possible that the numerical results to be given in Vol. II of the Annals may be 1.5 per cent higher than they should be in these units.

on Mount Wilson, both in 1905 and 1906, so that there can be little question that the large changes noted there are really solar changes and not of atmospheric or accidental origin.

The reality of the supposed solar origin of the changes of radiation observed is attested by many other evidences stated in Chapter VI, Part I, and Chapter III, Part III.

The temperature of the earth is shown to be in good agreement with the assumed value of the "solar constant," 2.1 calories. Indeed, it is shown that unless the albedo, or reflection, of the earth exceeds 37 per cent (a value here determined for it and based on observations at Washington and Mount Wilson), then the mean value of the solar constant can not exceed 2.33 calories, else the earth must be a better radiator than the "absolutely black body" or perfect radiator.

It is shown that the surface of the earth can radiate only very slightly to space, on account of the interference of clouds and water vapor to terrestrial radiation; and that the substance which maintains the earth at nearly constant temperature, by emitting to space radiation equal to that received by the sun, is principally the water vapor layer at 4,000 to 5,000 meters in elevation, whose mean temperature is 10° or more below 0° C.

There is introduced the conception of an "hypothetical earth," similar in dimensions and motions to the real earth, but hollow and like a soap bubble in thickness of wall; perfectly absorbing for solar radiation, and a perfect radiator for long waves; perfectly conducting for heat along parallels of latitude, but perfectly non-conducting along meridians of longitude. The temperature of this "hypothetical earth" is calculated for all times of the year, and for all latitudes, by the aid of the known value of the "solar constant" and the laws of radiation of perfect radiators.

A comparison is made between the annual march of temperature of the "hypothetical earth" and the observed annual march of temperature for 64 stations on the real earth. It is thereby shown that a given fractional change of solar radiation running its cycle in a year produces one-fourth the given fractional change in the absolute temperature of the "hypothetical earth," one-fourteenth of the given fractional change in the temperature of most inland stations, one twenty-fifth for coast stations; and one-fiftieth for small islands in great oceans. For a fluctuation of 5 per cent in solar radiation having a period of about a year there would be produced a change of only about 1° C. in the mean temperature of inland stations and only about 0.3° C. for island stations. The effects of more rapid changes of solar radiation would be less readily discernible in their effects on mean temperatures, but may nevertheless be of meteorological importance as promoters of atmospheric circulation.

From a comparison extending over thirty years of the temperatures of 47 well-distributed inland stations it appears probable that changes of solar radiation do produce, not infrequently, well-marked and recognizable changes of temperature over the continental areas of the world. Such changes of temperature would be predictable if accurate measurements of the solar radiation were systematically continued at a few favorable stations.

Numerous measurements of the comparative brightness of the center and edge of the solar disk indicate that the observed changes in solar radiation are attended by a variation of the transparency of the solar envelope, and perhaps are caused by it.

Many results of observation not here enumerated, such as the mean transparency of the upper and lower strata of air, the reflecting power of the clouds, the probable temperature of the sun, and the quality of the radiation of sunspots, will be found set forth both in words and by charts; and also a full

description of the apparatus and methods employed for the various kinds of research, and the sources and magnitude of the errors attending their use.

The work thus summarized seems definitely to fix the approximate average value of the intensity of solar radiation at about 2.1 calories per square centimeter per minute, and to show decisively that there is a marked fluctuation about this mean value, sufficient in magnitude to influence very perceptibly the climate, at least of inland stations, upon the earth. This being so, there is good reason for making the series of measurements of solar radiation as complete and continuous as possible for some years to come, in order to determine more thoroughly the causes and limits of the solar changes, and their precise effects upon climate. The former part of the study will involve further solar measurements, and the latter part a more complete study of meteorological records in connection with the solar measurements. Thus far no other observatory has been so well equipped as this one for the special kinds of measurement involved, and it will naturally be our task for some time to come to continue the work along the lines stated.

Respectfully submitted.

C. G. ABBOT,
Director of the Astrophysical Observatory

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

APPENDIX VI.

REPORT ON THE LIBRARY.

SIR: I have the honor to present the following report on the operations of the library of the Smithsonian Institution for the fiscal year ending June 30, 1907:

In the accession book of the Smithsonian deposit, Library of Congress, there have been recorded 1,741 volumes, 16,567 parts of volumes, 6,565 pamphlets, and 613 charts, making a total of 25,486 publications. The accession numbers run from 475,179 to 482,316. As in the past these publications have been sent to the Library of Congress, with the exception of a few needed for the scientific work of the Institution, which have been held. In transmitting the publications to the Library of Congress 275 boxes were used which, it is estimated, contained the equivalent of 11,000 volumes, a number which does not include the public documents presented to the Smithsonian Institution and sent direct to the Library of Congress as soon as received, without stamping or recording; or the public documents and other gifts to the Library of Congress received through the International Exchange Service.

The libraries of the Office, Astrophysical Observatory, and National Zoological Park have received 480 volumes and pamphlets, 1,849 parts of volumes, and 70 charts, making a total of 2,349, and a grand total, including the publications for the Smithsonian deposit and the Watts de Peyster Collection, of 28,123.

The parts of serial publications that were entered on the card catalogue numbered 26,499. Three hundred slips for completed volumes were made and 491 cards for new periodicals and annuals were added to the permanent record from the periodical recording desk.

Inaugural dissertations and academic publications were received from universities at the following places:

Baltimore (Johns Hopkins).	Lund.
Berlin.	Madison (Wisconsin).
Bern.	Marburg.
Bonn.	New York (Columbia).
Breslau.	Paris.
Erlangen.	Philadelphia (University of Pennsylvania).
Freiburg.	
Giessen.	Rostock.
Greifswald.	Strassburg.
Heidelberg.	Toulouse.
Helsingfors.	Tübingen.
Kiel.	Upsala.
Königsberg.	Utrecht.
Leipzig.	Würtzburg.
Louvain.	

The following technical high schools have also sent publications of the same character:

Berlin.	Darmstadt.	Karlsruhe.
Braunschweig.	Delft.	Munich.

In carrying out the plan to effect new exchanges and to secure missing parts to complete sets, 1,785 letters were written, resulting in 250 new periodicals

being added to the receipts, while about 600 defective series were partly or entirely completed. In addition to the letters referred to, 85 postal cards were sent and about 60 missing parts received in response.

The plan adopted by the International Catalogue of Scientific Literature of sending to authors lists of their scientific writings that have been indexed in the Catalogue, and requesting any that have not been cited, has been continued, with the result that nearly 500 authors' separates have been received, which will ultimately come to the library.

In the reading room there were withdrawn 40 bound volumes of periodicals and 3,485 parts of scientific periodicals and popular magazines, making a total of 3,525. The use of these publications, and those in the sectional libraries of the Institution, by persons from various bureaus of the Government has continued, but in the main the consultation has been by members of the staff.

The mail receipts numbered 34,500 packages, the publications contained therein being stamped and distributed for entry from the mail desk. About 5,000 acknowledgments were made on the regular form in addition to those for publications received in response to the requests of the Institution for exchange.

As the books formerly in the Secretary's library will no longer be kept separate from the general library, one change may be noted in the number of sectional libraries maintained in the Institution, there now being the office library and the employees' library, together with those of the Astrophysical Observatory, aerodromics, international exchanges, and law reference.

The employees' library.—The books added to the library numbered 40, 27 of which were presented by Mr. C. L. Pollard, and 80 volumes of magazines were bound. The number of books borrowed was 2,620, and the sending of a selected number of the books from this library to the National Zoological Park and the Bureau of American Ethnology each month has been continued.

The estate of S. P. Langley.—The estate of S. P. Langley turned over to the Institution his scientific library. These books have been stamped, entered, and placed in the divisions to which they relate.

The Watts de Peyster collection.—Gen. John Watts de Peyster continued, up to the time of his death, May 4, 1907, to present books relating to Napoleon Buonaparte and his time, together with volumes on other subjects for the Watts de Peyster collection in the Institution. There were received from this source during the year 288 volumes.

The art room.—The work of cataloguing the Marsh collection is progressing, and during the year 115 prints have been identified and cards made for them giving full information as to the engraver, the subject, the manner of execution, and the size of the print and plate.

Another important addition to the library was the receipt of three important series of publications from the Light-House Board; Annales des Ponts et Chaussées, 1831–1833, 152 volumes; Annales de Chimie, 1789–1815, 97 volumes, and Annales de Chimie et de Physique, 1816–1872, 139 volumes, which are a permanent transfer to the Institution.

In addition to the regular work in the library a partial bibliography of aeronautical literature, which included the papers by Langley, Chanute, Lilienthal, Herring, and Hargrave, and a bibliography of the writings of Dr. S. P. Langley were prepared for publication by the assistant librarian, Mr. Paul Brockett.

THE MUSEUM LIBRARY.

The Museum library has been fortunate in continuing to receive from Prof. O. T. Mason, Dr. W. L. Ralph, and Dr. C. A. White many scientific publications rtance in completing the sets and series in the Museum. Dr. C. W. Rich-

mond has continued to contribute to the library, and a number of rare scientific works not to be found elsewhere in the city have been received from him.

The library of the Museum has also benefited by the plan adopted by the International Catalogue of Scientific Literature of sending to authors lists of their scientific writings that have been entered in the catalogue and requesting any that have not been cited, as the larger number of the responses received are in the form of separates from periodicals, journals, etc., which are no longer desired for the Smithsonian deposit.

In the Museum library there are now 30,307 volumes, 47,642 unbound papers, and 108 manuscripts. The additions during the year consisted of 2,581 books, 3,567 pamphlets, and 111 parts of volumes. There were catalogued 1,301 books, of which 87 belonged to the Smithsonian library, and 3,567 pamphlets, of which 54 belonged to the Smithsonian library, and 13,215 parts of periodicals, of which 658 belonged to the Smithsonian library.

In connection with the entering of separates and periodicals, 721 memoranda were made reporting volumes and parts missing in the sets, together with a few titles of publications that were not represented in the library. The result of this work was the completing or partial filling up of 550 sets of publications.

Attention has been given to the preparation of volumes for binding, with the result that 1,020 books were sent to the Government bindery.

The number of books, periodicals, and pamphlets borrowed from the general library amounted to 34,859, including 9,397, which were assigned to the sectional libraries. This does not include, however, the large number of books consulted in the library but not withdrawn.

The sectional libraries established in the Museum have remained the same, the complete list now standing as follows:

Administration.	History.	Photography.
Administrative assistant.	Insects.	Physical anthropology.
Anthropology.	Mammals.	Prehistoric archæology.
Biology.	Marine invertebrates.	Reptiles.
Birds.	Materia medica.	Stratigraphic paleontology.
Botany.	Mesozoic fossils.	Superintendent.
Comparative anatomy.	Mineralogy.	Taxidermy.
Editor.	Mollusks.	Technology.
Ethnology.	Oriental archæology.	
Fishes.	Paleobotany.	
Geology.	Parasites.	

In the following table are summarized all the accessions during the year for the Smithsonian deposit, for the libraries of the office, Astrophysical Observatory, United States National Museum, and National Zoological Park. That of the Bureau of American Ethnology is not included, as it is separately administered:

Smithsonian deposit in the Library of Congress	25,486
Office, Astrophysical Observatory, International Exchanges	2,349
Watts de Peyster collection	288
United States National Museum library	6,259
Total	34,382

Respectfully submitted.

CYRUS ADLER,
Assistant Secretary, in Charge of Library and Exchanges.

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

APPENDIX VII.

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE: REGIONAL BUREAU FOR THE UNITED STATES.

SIR: I have the honor to submit the following report on the operations of the regional bureau for the United States of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1907:

This work is carried on under the authority of Congress, in accordance with the following item in the sundry civil appropriation bill:

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE: For the cooperation of the United States in the work of the International Catalogue of Scientific Literature, including the preparation of a classified index catalogue of American scientific publications for incorporation in the International Catalogue, the expense of clerk hire, the purchase of necessary books and periodicals, and other necessary incidental expenses, five thousand dollars, the same to be expended under the direction of the Secretary of the Smithsonian Institution.

The International Catalogue of Scientific Literature is a classified subject index of current scientific literature published in London in 17 annual volumes, the result of the combined cooperative work of regional bureaus established in all of the civilized countries of the world. All of the principal governments of the world are lending their aid to this important international undertaking. Each country collects, indexes, and classifies the current scientific literature published within its borders and furnishes to the central bureau in London the material thus prepared for publication in the annual volumes. The cost of preparation is borne by the countries taking part in the enterprise. The cost of printing and publishing is paid by the subscribers to the Catalogue. The enterprise was begun in 1901, and for the first five years of its existence the work in the United States was done through the Smithsonian Institution at the expense of its fund. For the present fiscal year Congress appropriated the sum of $5,000 to continue the work thus begun, and it was carried on as heretofore. The persons in charge of the work up to that date had been employees of the parent Institution, and being entirely familiar with the work, and having shown intelligence and devotion in carrying it out, they were, upon request, included in the classified civil service by an Executive order dated July 14, 1906.

One volume a year is devoted to each of the following-named subjects: Mathematics, mechanics, physics, chemistry, astronomy, meteorology (including terrestrial magnetism), mineralogy (including petrology and crystallography), geology, geography (mathematical and physical), paleontology, general biology, botany, zoology, human anatomy, physical anthropology, physiology (including experimental psycology, pharmacology, and experimental pathology), and bacteriology.

The citations are secured by regularly going through all of the journals listed to be examined, by a daily search through the large number of publications received by the Smithsonian Institution, and by the examination of all available lists. Nevertheless, so diverse are the places of publication in the United States that even this careful scrutiny was not considered sufficient, and there was compiled from the authors records in this office a list of papers,

by authors, which list was submitted to them for verification, criticisms, and additions. At the same time each author was requested to supply his separates to the Institution especially for the purposes of the Catalogue.

This method of keeping in direct communication with the authors of scientific papers is very desirable for many reasons, as it not only renders it possible to publish a complete Catalogue, but also aids materially in the proper and satisfactory classification of the work done, which from the point of view of the users of the Catalogue is of as great importance as it is to have the Catalogue complete.

During the year there were 28,629 references to American scientific literature completed for the central bureau, as follows:

Literature of—	
1901	384
1902	511
1903	862
1904	5,272
1905	9,022
1906	12,578
Total	28,629

Thirteen volumes of the Catalogue were received and delivered to the subscribers in this country, as follows:

Fourth annual issue: Chemistry, meteorology, general biology, botany, zoology, human anatomy, physical anthropology, and physiology, completing the issue.

Fifth annual issue: Mathematics, astronomy, geology, geography, and paleontology.

The practice has gradually been gaining ground in some of the regional bureaus of including references to technical and industrial matters, which while of great general interest do not come strictly within the definition of the scope of the work, which was to refer only to original published contributions to the physical and natural sciences. This matter has had careful consideration here, and it was deemed not only necessary but wise to adhere strictly to the plan agreed upon, since it was felt that a rigid following of the plan was essential where so many different nations were concerned, and for the further reason that an index can readily become too cumbersome for easy reference. Ultimately it may be possible to embrace in this Catalogue all records of progressive human interest, but it would seem at present the wisest policy to limit the work strictly to the original purpose.

The regional bureau in the United States was so organized in the beginning that it could at any time be expanded to embrace any subject found advisable to include in the work, but the bureau is at the present time worked to the limit of its capacity with the funds now at its disposal.

Several of the regional bureaus, including those of Germany, France, and Poland, are printing in periodical form the matter indexed by them. It was for a time hoped that this could be done in this country, and for several months, beginning with January 1, 1907, all scientific matter was currently collected, indexed, classified, and prepared as printer's proof ready for publication by the Institution, either monthly or quarterly, as a much-needed current classified index to American scientific literature. This method of publication would promptly furnish references to all of the scientific literature of the country practically as soon as published and probably a year in advance of the permanent assembled volumes published by the central bureau. The two methods of

publication would in no way conflict; the first would be a check list of current national work, while the second is a permanent classified international record.

The actual cost of printing a sufficient number of such a periodical would, however, have to be met by the private fund of the Institution. After thorough consideration it was decided that the outlay would not be justified. It is sincerely to be hoped that the publication of this material in the form mentioned, or its equivalent, can be soon begun.

Congress in the sundry civil bill approved March 4, 1907, appropriated $5,000 to carry on the work for the fiscal year ending June 30, 1908, it being the same amount as that appropriated for the past year.

I desire to acknowledge the zeal and fidelity of the staff who are under the immediate direction of Mr. Leonard C. Gunnell.

Very respectfully, yours, CYRUS ADLER,
Assistant Secretary, in Charge of Library and Exchanges.

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

APPENDIX VIII.

REPORT ON THE PUBLICATIONS.

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ending June 30, 1907:

I. Smithsonian Contributions to Knowledge.

In the series of the Smithsonian Contributions to Knowledge three memoirs were in press at the close of the fiscal year and several manuscripts were in preparation.

1692. Glaciers of the Canadian Rockies and Selkirks. Report of the Smithsonian Expedition of 1904. By William Hittell Sherzer, Ph. D. Quarto. Pages xii, 135, with 42 plates. Part of Volume XXXIV. In press.

The advertisement of this publication describes it as follows:

Dr. William H. Sherzer, professor of natural science at Michigan State Normal College, has brought together in the present memoir the results of an expedition undertaken by the Smithsonian Institution among the glaciers of the Canadian Rockies and Selkirks in the year 1904. The general objects of the research were to render available a description of some of the most accessible glaciers upon the American continent, to investigate to what extent the known glacial features of other portions of the world are reproduced in these American representatives, and to ascertain what additional light a study of similar features might shed upon glacier formation and upon some of the unsettled problems of Pleistocene geology.

A systematic survey was made of the Victoria and Wenkchemna glaciers in Alberta, and of the Yoho and Illecillewaet glaciers in British Columbia, located about 200 miles north of the boundary of the United States. The largest of these is the Yoho glacier, extending more than 3 miles below the névé field and 1 mile in width for two-thirds of its length. Doctor Sherzer investigated various surface features of each of these glaciers, the nature and cause of ice flow, the temperature of the ice at various depths and its relation to air temperature, the amount of surface melting, and the possible transference of material from the surface to the lower portion; their forward movement and the recession and advance of their extremities, and the general structure of glacial ice.

In summarizing the most important results Doctor Sherzer discusses the indicated physiographic changes in the region during the Mesozoic and Pleistocene periods; the question of precipitation of snow and rain, and the effect of climatic cycles on glacial movements, the structure of the ice as to stratification, shearing, blue bands, ice dykes, glacial granules, and the possible methods of their development. In discussing the theories of glacial motion the author expresses his conviction that the nature of the ice movement can be satisfactorily explained only upon the theory that under certain circumstances and within certain limits ice is capable of behaving as a plastic body—that is, capable of yielding continuously to stress without rupture—but the plasticity of ice, a crystalline substance, must be thought of as essentially different from that manifested by such amorphous substances as wax or asphaltum.

Doctor Sherzer also discusses the cause of the richness and variety of coloring of glaciers and glacial lakes.

1718. The Young of the Crayfishes Astacus and Cambarus. By E. A. Andrews. Quarto. Pages 79, with 10 plates. Part of Vol. XXXV. In press.

In this memoir there is described and illustrated the young of two kinds of crayfishes, one from Oregon and one from Maryland, representing the two most diverse forms in North America. The first, second, and third larval stages are determined, and there is described the hitherto unknown nature of successive mechanical attachments of the offspring to the parent.

1723. The Apodous Holothurians. A Monograph of the Synaptidæ and Molopadiidæ. Including a report on the representatives of these families in the collections of the United States National Museum. By Hubert Lyman Clark. Quarto. Pages 218+, with 13 plates. Part of Vol. XXXV. In press.

This memoir gives a summary of present knowledge of the two families of sea cucumbers, which lack tube feet.

The most important feature of the work is the recognition of the changes taking place in the maturing and senescence of individual holothurians, particularly in the family Molopadiidæ. As a result of this, radical changes in nomenclature have been necessary, but every effort has been made to have the system adopted accord with the most widely accepted codes, and thus be as stable as possible. Special attention has been given to geographical distribution, but the work in this line is chiefly of value as a summary of our present very inadequate knowledge. Artificial keys to genera and species have been freely used with the intention of making the work as useful as possible to all subsequent investigators, and the numerous figures, most of which are copied from other writers, are given with the same end in view.

11. *Smithsonian Miscellaneous Collections.*

In the series of Smithsonian Miscellaneous Collections there were published 24 papers in the Quarterly Issue, Vol. III, Parts 3 and 4, and Vol. IV, Part 1, as follows:

1656. Smithsonian Miscellaneous Collections. Quarterly Issue. Vol. III, Part 3 (containing Nos. 1657–1664). Octavo. Pages 241–379, with plates LIX–LXIII.

1657. The Species of Mosquitoes in the Genus Megarhinus. By Harrison G. Dyar and Frederick Knab. Published September 27, 1906. Octavo. Pages 241–258.

1658. A Contribution to the Knowledge of some South American Hymenoptera, chiefly from Paraguay. By C. Schrottky. Published February 4, 1907. Octavo. Pages 259–274.

1659. Description of a New Squirrel of the Sciurus prevostii Group from Pulo Temiang, West Coast of Borneo. By Marcus Ward Lyon, jr. Published February 4, 1907. Octavo. Pages 275–276.

1660. The Squirrels of the Sciurus vittatus Group in Sumatra. By Marcus Ward Lyon, jr. Published February 4, 1907. Octavo. Pages 277–283.

1661. A study of the Butterfly Wing-Venation, with special regard to the radial vein of the front wing. By Thomas J. Headlee. Published February 4, 1907. Octavo. Pages 284–296, with plates LIX–LXIII.

1662. Some Noteworthy Extra-European Cyprinids. By Theodore Gill. Published February 4, 1907. Octavo. Pages 297–340.

1663. A review of the American Volutidæ. By William Healey Dall. Published February 4, 1907. Pages 341–373.

1664. Notes to Quarterly Issue. Vol. III. Part 3. Octavo. Pages 374–379.

1695. Smithsonian Miscellaneous Collections. Quarterly Issue. Vol. III, Part 4 (containing Nos. 1696–1701). Octavo. Pages 381–567, plates LXIV–LXX, and table of contents and index to Volume III of the Quarterly Issue.

1696. The breeding habits of the Florida alligator. By Albert M. Reese. Published May 4, 1907. Octavo. Pages 381–387, with plates LXIV–LXV.

1697. Life histories of Toadfishes (Batrachoidids), compared with those of Weavers (Trachinids) and Stargazers (Uranoscopids). By Theodore Gill. Published May 4, 1907. Octavo. Pages 388–427.

1698. The letter of Dr. Diego Alvarez Chanca, dated 1494, relating to the second voyage of Columbus to America (being the first written document on the natural history, ethnography, and ethnology of America). Translated, with notes, by A. M. Fernandez de Ybarra. Published May 4, 1907. Octavo. Pages 428–457, with plate LXVI.

1699. The origin of the so-called Atlantic animals and plants of western Norway. By Leonhard Stejneger. Published May 4, 1907. Octavo. Pages 458–513, with plates LXVII–LXX.

1700. Manners and customs of the Tagbanuas and other tribes of the Island of Palawan, Philippines. By Manuel Hugo Venturello. Published May 4, 1907. Octavo. Pages 514–558.

1701. Notes to Quarterly Issue, Vol. III, Part 4. Octavo. Pages 559–562.

1702. Smithsonian Miscellaneous Collections. (Quarterly Issue. Vol. III), Vol. XLVIII. Octavo. Pages vii, 1–567, with plates I–LXX.

1703. Smithsonian Miscellaneous Collections. (Quarterly Issue), Vol. IV, Part 1 (containing Nos. 1704–1716). Octavo. Pages 1–131, with plates I–XIV.

1704. Notes on some Upper Cretaceous Volutidæ, with descriptions of a new species and a revision of the groups to which they belong. By W. H. Dall. Published March 17, 1907. Octavo. Pages 1–23.

1705. Notes on some squirrels of the Sciurus hippurus group, with descriptions of two new species. By Marcus W. Lyon, jr. Published April 8, 1907. Octavo. Pages 24–29.

1706. A new Calamarine snake from the Philippine Islands. By Leonhard Stejneger. Published April 8, 1907. Octavo. Pages 30–31.

1707. Additional notes on Mexican plants of the genus Ribes. By J. N. Rose. Published May 1, 1907. Octavo. Page 32.

1708. Morkillia, a new name for the genus Chitonia; with description of a new species. By J. N. Rose and Joseph H. Painter. Published May 1, 1907. Octavo. Pages 33–34.

1709. The "Webster" ruin in Southern Rhodesia, Africa. By Edward M. Andrews. Published May 1, 1907. Octavo. Pages 35–47, with plates I–III.

1710. The Bororo Indians of Matto Grosso, Brazil. By W. A. Cook. Published May 1, 1907. Octavo. Pages 48–62, with plates IV, V.

1711. Cactus Maxonii, a new cactus from Guatemala. By J. N. Rose. Published June 15, 1907. Octavo. Pages 63–64, with plate VI.

1712. On the clasping organs attaching the hind to the fore wings in Hymenoptera. By Leo Walter. Published June 24, 1907. Octavo. Pages 65–87, with plates VII–X.

1713. Notes on Mammals collected at Mount Rainier, Washington. By M. W. Lyon, jr. Published June 27, 1907. Octavo. Pages 89–92.

1714. The Archaic monetary terms of the United States. By C. A. White. Published June 27, 1907. Octavo. Pages 93–104.

1715. Description of a collection of Kootanie plants from the Great Falls coal field of Montana. By F. H. Knowlton. Published June 27, 1907. Octavo. Pages 105–128, with plates XI–XIV.

1716. Notes to Quarterly Issue, Vol. IV, Part 1. Octavo. Pages 129–131.

Among the papers in press for the Quarterly Issue at the close of the fiscal year may be mentioned: The Air-Sacs of the Pigeon, by Bruno Müller; and Excavations at Casa Grande, Arizona, in 1906 and 1907, by J. Walter Fewkes.

There was also published in the regular series of the Smithsonian Miscellaneous Collections the following report of researches under a grant from the Hodgkins fund:

1654. Researches on the Attainment of Very Low Temperatures. Part II.—Further notes on the Self Intensive Process for Liquefying Gases. By Morris

W. Travers (with A. G. C. Gwyer and F. L. Usher). Part of Vol. XLIX. Octavo. Pages 1–14.

There was in press at the close of the year additional copies of the Smithsonian Meteorological Tables in the form of a third edition of that work.

The following work was issued in continuation of the Catalogue prepared by Prof. Edward S. Holden, issued by the Smithsonian Institution in 1898, No. 1087.

1721. Catalogue of Earthquakes on the Pacific Coast, 1897 to 1906. By Alexander G. McAdie. Part of Volume XLIX. Octavo. Pages 64.

There was in press at the close of the year a work on crabs of the North Pacific under the following title:

1717. Report on the Crustacea (Brachyura and Anomura), collected by the North Pacific Exploring Expedition, 1853–1856. By William Stimpson. Octavo. Pages 240, with 26 plates. Part of Volume XLIX.

The work, written by Doctor Stimpson, who died in 1892, is edited by Miss Mary J. Rathbun. In the introductory note the editor thus describes the character of the report and the causes for delay in its publication:

The North Pacific Exploring Expedition was sent out by the Navy Department under an appropriation from Congress in 1852, for "building or purchase of suitable vessels, and for prosecuting a survey and reconnoissance, for naval and commercial purposes, of such parts of Behring Straits, of the North Pacific Ocean, and the China seas, as are frequented by American whale ships, and by trading vessels in their routes between the United States and China." The expedition set sail in June, 1853, and returned in 1856. Capt. C. Ringgold, U. S. Navy, was placed in command, but, being recalled to the United States in 1854, he was superseded by Capt. John Rodgers, U. S. Navy. William Stimpson acted as zoologist. After leaving Norfolk the five vessels in service touched at Madeira, and then proceeded to Hongkong via the Cape of Good Hope. On this passage the sloop *Vincennes* and the brig *Porpoise* took the more southerly route to Van Diemens Land, thence through the Coral Seas, and by the Caroline, Ladrone, and Bashee islands, while the steamer *John Hancock* and the other two vessels of the fleet traversed the straits of Sunda and Gaspar, the Carimata and Billeton passages, and the Sooloo Sea. Subsequently the expedition advanced northward, continuing work along the coasts of Japan and Kamchatka, in Bering Strait, on the coast of California, and at Tahiti, returning around the Cape of Good Hope.

Of the vast collections obtained, it was estimated that the Crustacea numbered 980 species.

A few years after his return to the United States, Dr. William Stimpson became director of the Chicago Academy of Sciences, and moved to that place nearly all of the invertebrate material obtained by the expedition and belonging to the United States Government. Several preliminary papers had been prepared and published by him in the Proceedings of the Academy of Natural Sciences of Philadelphia, when the collections with notes and drawings were destroyed by the memorable fire in 1871. In a statement of losses sustained, Doctor Stimpson enumerated the manuscript and drawings of the final report on the Crustacea Brachyura and Anomura. After his death in 1872, however, this report was discovered at the Navy Department and was sent to the Smithsonian Institution, where it has remainded to the present time unpublished.

In the meantime there are few students of the higher Crustacea who have not felt the need of more light on those rare genera and species known only from brief Latin diagnoses.

The following report has been treated as an historical document, and is published substantially as it was written by the author, the only additions being the references to his preliminary descriptions and the footnotes giving the current or accepted name where it differs from that used by Doctor Stimpson. It is hoped that the value of the descriptions will more than compensate for the antiquated nomenclature.

There was also in press at the close of the year in the series of Smithsonian Miscellaneous Collections the following publication:

1720. Samuel Pierpont Langley, Secretary of the Smithsonian Institution, [illegible]–1906. Memorial meeting December 3, 1906. Addresses by Doctor White, [illegible]r Pickering, and Mr. Chanute. Octavo. Pages 49. Part of Volume [illegible].

III. *Smithsonian Annual Reports.*

The Annual Report for 1905 was distributed early in the fiscal year:

1667. Annual Report of the Board of Regents of the Smithsonian Institution. Showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1906. Octavo. Pages i-liv, 1–576, with 48 plates.

The following papers included in the Annnual Report of the Board of Regents for 1905 were issued separately in pamphlet form:

1668. Journal of Proceedings of the Board of Regents of the Smithsonian Institution at Meetings of December 6, 1904, and January 25, and March 6, 1905. Report of Executive Committee. Acts and resolution of Congress. Octavo. Pages xi-liv.

1669. New Measurements of the Distance of the Sun. By A. R. Hinks. Octavo. Pages 101–118.

1670. Photographing Lightning with a Moving Camera. By Alex. Larsen. Octavo. Pages 119–127, with plates I–IV.

1671. The Tantalum Lamp. By W. von Bolton and O. Feuerlein. Octavo. Pages 129–140.

1672. Some Refinements of Mechanical Science. By Ambrose Swasey. Octavo. Pages 141–150.

1673. Progress in Radiography. By L. Gastine. Octavo. Pages 151–161, with plates I–VIII.

1674. History of Photography. By Robert Hunt. Octavo. Pages 163–192, with plates I–IV.

1675. The Genesis of the Diamond. By Gardner F. Williams. Octavo. Pages 193–209.

1676. A description of the Big Diamond recently found in the Premier Mine, Transvaal. By F. H. Hatch and G. S. Corstorphine. Octavo. Pages 211–213, with plates I, II.

1677. Gold in Science and Industry. By G. T. Beilby. Octavo. Pages 215–234.

1678. Submarine Navigation. By Sir William H. White. Octavo. Pages 235–245.

1679. Liberia. By Sir Harry Johnston. Octavo. Pages 247–264, with plates I–VII.

1680. Geographical Results of the Tibet Mission. By Sir Frank Younghusband. Octavo. Pages 265–277, with plates I–IV.

1681. The Development of Rhodesia and its Railway System in Relation to Oceanic Highways. By J. T. P. Heatley. Octavo. Pages 279–292, with plate I.

1682. The Ethics of Japan. By Baron Kencho Suyematsu. Octavo. Pages 293–307.

1683. Plague in India. By Charles Creighton. Octavo. Pages 309–338.

1684. The Fight against Yellow Fever. By A. Dastre. Octavo. Pages 339–350.

1685. Luminosity in Plants. By Hans Molisch. Octavo. Pages 351–362.

1686. Notes on the Victoria Lyre Bird (Menura Victoriæ). By A. E. Kitson. Octavo. Pages 363–374, with plates I–VI.

1687. The Influence of Physical Conditions in the Genesis of Species. By Joel A. Allen. Octavo. Pages 375–402.

1688. Parental Care Among Fresh-Water Fishes. By Theodore Gill. Octavo. Pages 403–531, with plate I.

1689. On the Relations between the United States of America and Germany, especially in the field of Science. By Wilhelm Waldeyer. Octavo. Pages 533–547.

1690. Walter Reed. A Memoir. By Walter D. McCaw. Octavo. Pages 549–556, with plate I.

1691. Rudolph Albert von Kölliker, M. D. By William Stirling. Octavo. Pages 557–562, with plate I.

The Acting Secretary's Report for 1906, forming a part of the Annual Report of the Board of Regents to Congress, was printed as usual in pamphlet form in November, 1906, for the use of the Board, and in January a larger edition was issued for public distribution, as follows:

1693. Report of the Acting Secretary of the Smithsonian Institution for the year ending June 30, 1906. Octavo. Pages 91.

There was also issued for the use of the Regents a small edition of the Proceedings of the Board.

1743. Proceedings of Board of Regents for the year ending June 30, 1906. Report of Executive Committee. Acts and Resolutions of Congress. Octavo. Pages XI–LI.

The full report for 1906 was in type, although not ready for distribution at the close of the fiscal year.

1742. Annual Report of the Board of Regents of the Smithsonian Institution, showing the Operations and Expenditures and Condition of the Institution for the year ending June 30, 1906. Octavo. Pages i–ii, 1–546, with 43 plates.

The contents of the General Appendix are as follows:

1744. The Smithsonian Institution. Octavo. Pages 97–102.

1745. Modern Theories of Electricity and Matter. By Madame Curie. Octavo. Pages 103–115.

1746. Radioactivity. By Franz Himstedt. Octavo. Pages 117–130.

1747. Recent Advances in Wireless Telegraphy. By G. Marconi. Octavo. Pages 131–145.

1748. Revisions of the Theory of Electrolysis. By H. S. Carhart. Octavo. Pages 147–160.

1749. Recent Progress in Astronomical Research. By C. G. Abbot. Octavo. Pages 161–171, with plates I, II.

1750. Astronomy on Mont Blanc. By H. Radau. Octavo. Pages 173–186.

1751. The Problem of the Metalliferous Veins. By James Furman Kemp. Octavo. Pages 187–206.

1752. Iron Ore Reserves. By Charles Kenneth Leith. Octavo. Pages 207–214.

1753. The Geology of the Diamond and Carbonado Washings of Bahia, Brazil. By Orville A. Derby. Octavo. Pages 215–221, with plates I, II.

1754. The Eruption of Vesuvius in April, 1906. By A. Lacroix. Octavo. Pages 223–248, with plates I–XIV.

1755. To the North Magnetic Pole and through the Northwest Passage. By Roald Amundsen. Octavo. Pages 249–273, with plates I–VI.

1756. Iceland: Its History and Inhabitants. By Herr Jon Stefansson. Octavo. Pages 275–294.

1757. The Recently Discovered Tertiary Vertebrata of Egypt. By C. W. A[illegible]ws. Octavo. Pages 295–307.

1[illegible] Polyembryony and the Determination of Sex. By E. Bugnion. Octavo. [illegible]–320.

1[illegible]. A Contribution to the Morphology of the Mammoth, Elephas primi[illegible]us [illegible]umenbach; with an explanation of my attempt at a restoration. By [illegible]nmayer. Octavo. Pages 321–331, with plate I.

1[illegible] Heredity. By L. Cuénot. Octavo. Pages 335–344.

1[illegible]. The Bisons of the Caucasus. By A. Yermoloff. Octavo. Pages 345–[illegible] with plates I, II.

1762. The Founding of Colonies by Atta sexdens. By Jakob Huber. Octavo. Pages 355–372, with plates I–V.

1763. Quaternary Human Remains in Central Europe. By Hugues Obermaier. Octavo. Pages 373–397.

1764. The Origin of the Slavs. By Professor Zaborowski. Octavo. Pages 399–422.

1765. Scalping in America. By Georg Friederici. Octavo. Pages 423–438.

1766. Zoology and Medicine. By Raphael Blanchard. Octavo. Pages 439–452.

1767. The Rôle of Chemistry in Painting. By Eugene Lemaire. Octavo. Pages 453–458, with plate I.

1768. Oils, Varnishes, and Mediums Used in the Painting of Pictures. By A. P. Laurie. Octavo. Pages 459–468, with plate I.

1769. National Reclamation of Arid Lands. By C. J. Blanchard. Octavo. Pages 469–492, with plates I–VII.

1770. International Science. By Arthur Schuster. Octavo. Pages 493–514.

1771. Samuel Pierpont Langley. By Cyrus Adler. Octavo. Pages 515–533.

IV. *Special Publications.*

There was issued during the year a special publication in the form of the Smithsonian Contributions to Knowledge, but it was not included in that series since only a limited number of copies of the accompanying plate were available. The work is entitled:

1694. Remarks on the Type of the Fossil Cetacean Agorophius pygmaeus (Müller). By Frederick W. True. City of Washington: Published by the Smithsonian Institution, 1907. Quarto. Pages 8, with 1 plate.

The author in the first paragraph of the work says:

> Somewhat more than fifty years ago the Smithsonian Institution, then recently founded, undertook the publication of a number of memoirs by Prof. Louis Agassiz, and prepared some lithographic plates to accompany them. Before the work had proceeded very far, Professor Agassiz made other arrangements for the publication of his writings and the plates were never issued. One of these unpublished plates represents the type specimen of a very remarkable species of fossil cetacean, now known as *Agorophius pygmaeus* (Müller), and on account of circumstances which are detailed below it has been thought desirable to issue it, with a brief explanation as to its importance.

As a special publication, No. 1722, there was printed an octavo pamphlet of 38 pages entitled "Classified List of Smithsonian Publications available for Distribution April, 1907."

For general distribution to correspondents there was published, without bearing a serial number, a duodecimo pamphlet of six pages entitled "The Smithsonian Institution, at Washington, for the Increase and Diffusion of Knowledge among Men." This pamphlet gives a brief description of the functions of the Institution and its branches for the general information of the public.

V. *Publications of United States National Museum.*

The publications of the National Museum are: (*a*) The Annual Report, forming a separate volume of the Report to Congress by the Board of Regents of the Smithsonian Institution; (*b*) the Proceedings of the United States National Museum; (*c*) the Bulletin of the United States National Museum.

The publications issued during the year are enumerated in the Report on the National Museum. These included the Annual Reports for 1905 and 1906; volumes 31 and 32 of the Proceedings; volume 2 of Bulletin 53; Part 1 of Bulletin 56; Bulletin 57; a supplement to Bulletin 51; Volume XI of Contributions to the National Herbarium and three parts of Volume X of the same series. Three other bulletins were in press at the close of the year.

VI. *Publications of the Bureau of American Ethnology.*

The twenty-sixth annual report of the Bureau of American Ethnology and Bulletins 33, 34, 35, and 36 were sent to the printer during the year. Bulletins 31 and 32 were published in July. Part 1 of Bulletin 30, Handbook of American Indians, appeared in March, and the twenty-fourth annual report in May. A list of publications of the Bureau and a special article on Indian missions were issued in June. These publications are elsewhere described in detail in the report on the Bureau.

VII. *Report of the American Historical Association.*

The annual report of the American Historical Association for the year 1905 was sent to the printer in May, 1906, and Volume I was completed in November of that year. Volume II, however, comprising a complete bibliography of the publications of American historical societies for more than a century, had not been issued at the close of the fiscal year.

The manuscript of the report for 1906 was received in May, 1907, but was not forwarded to the printer until after the close of the fiscal year.

VIII. *Report of the Daughters of the American Revolution.*

The ninth report of the National Society of the Daughters of the American Revolution was received from the society in February, 1907, and submitted to Congress in accordance with law.

IX. *Smithsonian Committee on Printing.*

The editor has served as secretary of the Smithsonian advisory committee on printing and publication. To this committee have been referred the manuscripts proposed for publication by the various branches of the Institution, also those offered for printing in the Quarterly Issue of the Smithsonian Miscellaneous Collections. The committee has also passed upon blank forms for current use in the Institution and its branches. The committee considered and reported to the Secretary on various questions relating in general to printing and publication. Twenty-six meetings were held during the year and 101 manuscripts were reported upon.

X. *Press Abstracts of Publications.*

Beginning in March, 1907, an editorial assistant was assigned to the preparation of abstracts of such publications of the Institution and its branches as could be put in popular language for the use of newspapers throughout the country. There has also been sent out a number of brief accounts of current investigations and longer descriptions of general work in the National Museum, the International Exchanges, the Astrophysical Observatory, the Zoological Park, and other branches of the Institution's work.

Respectfully submitted.

A. HOWARD CLARK,
Editor.

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1907

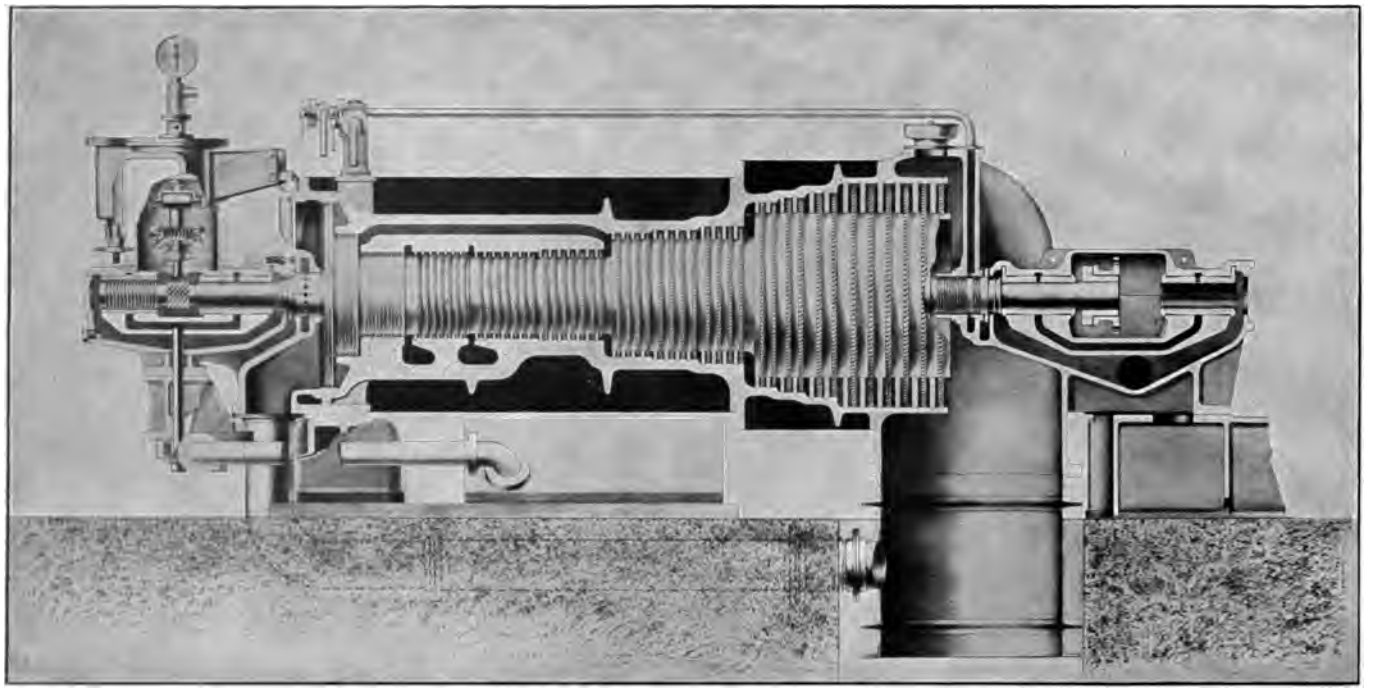
ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the Secretary, induced in part by the discontinuance of an annual summary of progress which for thirty years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1907.



SECTION THROUGH COMPOUND STEAM TURBINE.

THE STEAM TURBINE ON LAND AND AT SEA.[a]

By Hon. CHARLES A. PARSONS, C. B., M. A., D. Sc., F. R. S., M. R. I.

It was with some diffidence that I accepted the subject of steam turbines on land and at sea for this evening's lecture, for since I had the privilege of dealing with this subject six years ago in this room, there seemed to me to be very little new to add, either from a scientific or a practical point of view, which had not then been to some extent considered. However, after consideration, there seemed to be a hope that an account of some further developments during the last six years on land and on sea, and a more extended description of the mechanics of the turbine and its applications, might prove of some interest, in view of the more general adoption of the turbine principle for the generation of electricity, for the propulsion of vessels, and for driving air-compressors, fans, and pumps.

Six years ago there were 75,000 horsepower of turbines on land, and 25,000 on sea. At the present time there are more than 2,000,000 horsepower at work on land and 800,000 horsepower at work or building for use at sea.

There are at present afloat, equipped with turbines, three pleasure steamers, nine cross-channel steamers, five ocean-going vessels, three Atlantic liners, six yachts, three destroyers, and two cruisers.

Yet it can not be said that the turbine engine is superseding the reciprocating engine generally, although this is undoubtedly to some extent the case in certain fields of work.

On land the chief application of the turbine is found in large electrical generating stations, and its adoption in preference to the piston engine, in its most perfect development of compound, triple, or quadruple expansion engine, is becoming general in this field of work.

At sea, its use is commencing to extend for all the larger and faster class of ships; for cross-channel steamers it has found great favor, and for Atlantic liners and ships of war it is being used to a

[a] Paper read before the Royal Institution of Great Britain at its weekly evening meeting, Friday, May 4, 1906. Reprinted, by permission, from the Transactions of the Royal Institution.

more and more considerable extent, and this tendency is not confined alone to England, but is shown also on the Continent, and in the United States and Japan. It will give a clearer idea of the subject if we first of all examine more closely the characteristics of the steam turbine, and generally how it works.

All turbines derive their power from the impact of the steam, or, more correctly speaking, from the momentum of the steam, flowing through them, just as a windmill receives its power from the wind.

There are three principal types of turbines now in general use, as well as some which may be described as admixtures of these three classes. They differ essentially in some respects, more particularly in their methods of extracting the power from the steam.

The first to receive commercial application, 1884, was the compound or multiple expansion steam turbine; the second was the De Laval or single-bucket wheel, in 1888, driven by the expanding steam jet; and, lastly, the Curtis turbine, in 1896, which comprises some of the principal features of the others combined with a sinuous treatment of the steam.

In the compound turbine, the steam is caused to flow through a series of many turbine elements of gradually increasing size, graduated so as to allow of the expansion of steam in small increments of volume at each element, these increments of volume corresponding to the fall of pressure necessary to cause the steam to flow through each element. Each element consists of a row of guide blades and a row of moving blades. The guide blades are attached in circumferential rows to the case and project inwardly, and the moving blades are attached in rows to a drum and project outwardly. The end of the blades throughout the turbine nearly touch the drum and case respectively.

To form some idea of the forces at work in a turbine we should consider, with approximate accuracy, that the steam flows through the turbine with a force about ten times as great as that of the strongest hurricane; and though the force acting on each blade is small, perhaps only a few ounces, or in the largest only a few pounds, yet in the aggregate the force is great and can propel large ships or drive large dynamos.

The important factors upon which the proportions of the turbine are based are the pressures, velocities and percentages of moisture in the steam, as it gradually expands from turbine row to turbine row.

The blades of the turbine are made of rolled and drawn brass, well shaped, and polished so as to reduce the frictional losses in the steam to a minimum. The steam enters all round the shaft and first traverses the shortest blades on the smallest drum, then through larger and larger blades set on larger and larger drums, and so on till as it leaves the last blades it is expanded about 100-fold in vol-

ume. At the opposite end to the blade drums are seen the balance pistons, or dummy drums, which serve to balance the end pressure of the steam, and are kept steam-tight with the casing by packing grooves on the dummy drums which rotate in close proximity to corresponding but stationary brass rings keyed into the case.

In land turbines, for driving dynamos or other fast moving machinery, no end-pressure on the shaft is required, nor is it permissible because of the mechanical difficulties met with in thrust-bearings carrying heavy end-pressure and rotating at high speed, and therefore balance pistons are provided, which, while being practically steam-tight, serve to balance all end-pressure arising from the steam acting upon the rotating barrels and vanes.

In marine turbines, on the other hand, the dummy drums are so proportioned as to leave an unbalanced end-pressure, which counteracts and balances the thrust of the propeller, thus relieving the thrust-bearing from pressure.

The bearings of the engine, it will be seen, have only to support the weight of the rotating part of the engine; this is comparatively small, and as continuous lubrication is provided by an oil pump which circulates the oil continuously through the journals round and round, there is practically no wear, even after years of continuous work; and the maintenance of the shaft in a truly central position relatively to the casing, which is of great importance, is easily maintained in practice.

Before proceeding further with the examination of the compound steam turbine, let us consider the De Laval steam turbine introduced by Doctor De Laval, of Stockholm, in 1888.

In this turbine the steam at full pressure issues from a diverging conical jet, so formed and proportioned that the steam after passing through the neck of the jet enters a gradually divergent passage of increasing cross-section, in which it expands; the result being that nearly the whole available energy in the steam is utilized in imparting to it a very high velocity, reaching, with 100-pound boiler pressure and a good vacuum, as much as 4,200 feet per second, and the discovery of this property of the expanding jet is due chiefly to Doctor De Laval.

This rapidly moving column of expanded steam is directed against cupped steel buckets on the periphery of a wheel made of the strongest steel, the wheel being shaped so as to permit of the highest peripheral velocity consistent with safety, which may be from 800 to 1,200 feet per second; the steam, by striking the cups and reacting, partly by velocity of flow and partly by elastic gaseous rebound from the concave surface of the cups, leaves the wheel with a con-

siderable backward velocity, and to obtain the highest efficiency it is necessary to reduce this backward velocity by increasing the velocity of the wheel to the uttermost. The strongest materials, however, do not permit of a close approach to the speed necessary for the maximum efficiency; yet in this turbine, owing to the comparative absence of losses, which are present to some extent in the other types (and which we will consider presently), the efficiency of this turbine compares favorably for moderate and small powers.

In this beautiful construction, developed with mechanical skill and guided by an intimate acquaintance with the properties of steam and materials, there are many minor features of interest. Among them may be mentioned the elastic shaft, to permit of the rotation of the turbine wheel about its dynamic axis. A device, consisting of frictional damping washers, which had the same purpose as this elastic shaft, was used in 1885 in the early development of the compound steam turbine. It was superseded in 1892 by the damping effect of thin films of oil between several concentric loosely-fitting tubes surrounding the bearings.

The De Laval turbine has for many years been extensively used on the Continent and in this country, in sizes up to about 400 horsepower. Its chief use has been for the driving of dynamos, pumps, fans, and motive power generally; and, owing to its very high angular speed, it is necessary in most cases to use gearing, except when driving very fast-running centrifugal pumps and fans.

The gearing is of steel, and it is accurately cut with very fine spiral teeth, and it works satisfactorily even at the speed of 30,000 revolutions per minute.

Let us now consider the Curtis turbine. It ranks in a class by itself, because it comprises the principle of the sinuous treatment of expanded steam first put into extended commercial use by Mr. Curtis under the auspices of the General Electric Company of America.

This sinuous treatment of the steam consists in giving to it a high initial velocity by passing it through a jet of the De Laval type, or a group of such jets; it then impinges on a ring of bucket-blades like those used by De Laval, and after leaving the first row of such blades it is caught by a ring or a sector of stationary bucket-blades set in the reverse direction, and by them its direction is changed into that of the next succeeding row of moving blades (there may be three rows of moving blades in all and two sectors of fixed blades); and the height of each succeeding row is increased, to allow a greater area for the steam as it flags in velocity after each rebound between the moving and fixed blades.

The object of this treatment is to transfer a large percentage of the kinetic energy of the rapidly moving steam to the moving blades

and wheel, without the necessity of very high peripheral speeds of blades, such as are necessary with the single-wheel type. As regards, however, " multiple series action," the principle resembles the compound turbine.

The expansion process in nozzles, and subsequent sinuous treatment of the steam, is repeated several times by four or more similar wheels on the same axis, but in separate steam-tight chambers, until the steam is fully expanded.

If there are four such operations, the velocity of outflow from the nozzles will be about 2,000 feet per second, and the peripheral velocity of wheel about 400 feet per second; and at each operation the steam is expanded through one-fourth of the whole range, and at each it is brought to rest before flowing to the next chamber through the jets.

A great many other varieties of the turbine have been proposed, and some have received a limited application. The Rateau, the Reidler Stumpf, the Zoelly, the Escher Wyss, and many others might be mentioned as varieties of the three fundamental turbines we have considered; indeed in some cases the variation would appear to have been only a retrograde step, and represents some discarded form tried by one of the originators of the three fundamental types.

As far as we can gather from the history of the steam turbine, it may be said broadly that all the chief features at present in use in turbines have been suggested or described in the rough by experimenters long ago in the hundred and more patents prior to 1880.

For instance, Hero of Alexandria, B. C. 130, made a reaction wheel.

William Gilmore first suggested the compound steam turbine in 1837.

Matthew Heath first enunciated the principle of the diverging conical jet in 1838.

James Pilbrow in 1842 used cupped buckets, and suggested a sinuous treatment of the steam.

Robert Wilson developed the compound steam turbine to a considerable extent in 1848.

It would take too long to trace the initiation of each idea, but we may say, in the light of recent experience, that most, if not all, the designs showed a want of knowledge of the properties of steam and materials, and could not have given a satisfactory performance.

Let us again recur to the compound turbine, and look more closely into the principles of its working, and more particularly consider the course of the steam in its passage through the vanes or blades of the engine.

Viewing the turbine as a whole we see that the steam passes through the forest of fixed and moving blades just as water flows from a lake

of higher level through a series of rapids and intervening pools to a lake of lower level. The boiler corresponding to the lake of higher level and the condenser to that of lower level.

In the flow through the turbine the steam is repeatedly gathering a little velocity from the small falls of pressure, which is as soon checked and its energy transferred to the blades, over and over again; fifty to one hundred times is this repeated before it is fully expanded and escapes into the condenser.

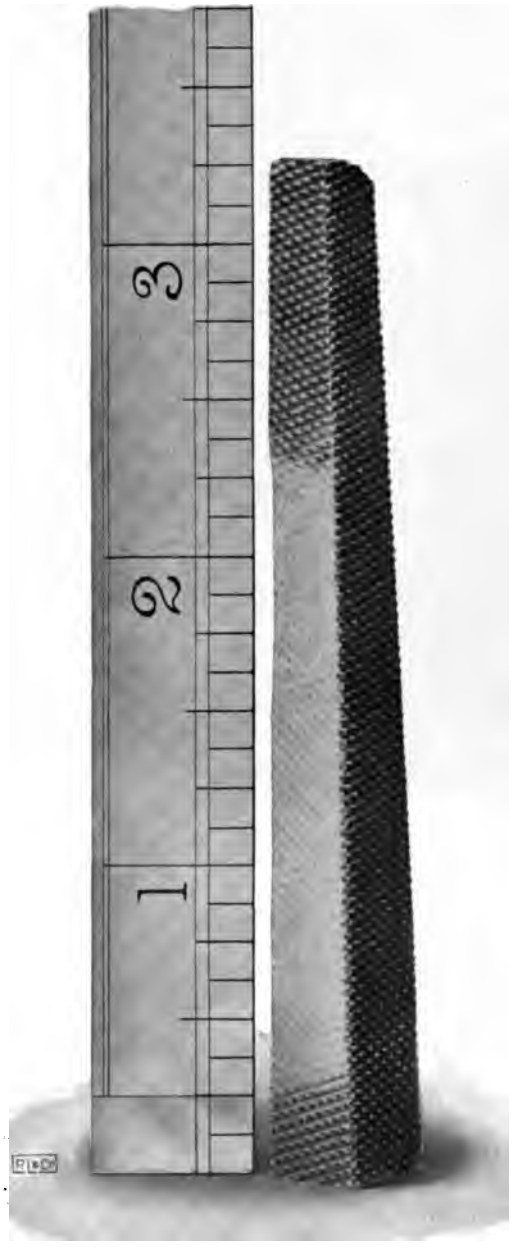
The number of blades in a steam turbine is very great; in a 2,000-horsepower engine it may be from 20,000 to 50,000 and the surface speed of the several barrels of the turbine will be from 150 to 300 feet per second. In such an engine it is arranged that the lineal velocity of the blades will approximate to one-half that of the tangential component of the steam issuing from the guide blades. The blades, as we have seen, are curved, with thickened backs, and are smooth; the steam therefore flows around them, and past them, without much loss by shock or eddy current or frictional loss. The proportions of turbine as regards diameter, height of blade, and blade openings are such that, under average working conditions, the correct expansion of the steam shall be attained, and the fall in pressure and velocity of steam at each turbine of the series shall be such as to secure that of the highest efficiency.

When a turbine is tested the pressures at many points along the barrel are recorded, and the calculated pressures confirmed and verified by experiment, and these are usually in close accord. As the result of data accumulated from experiments on many turbines, the probable horsepower that will be obtained from a given design of turbine can be predicted with as much accuracy as in the case of the reciprocating engine. The best results that have been obtained from large turbines show that about 70 per cent of the available energy in the steam is converted into brake horsepower; and where, we may inquire, has the other 30 per cent gone to?

The chief losses of efficiency in all steam turbines are due to three principal causes: Firstly, to skin-friction of the steam coursing at high temperature through the small openings between the blades; secondly, to unavoidable leakages; and, thirdly, to eddy-current losses arising from insufficient blade velocity and errors of workmanship.

The first of these losses, the friction of the steam, is reduced by superheating, and thus partially removing the fluid frictional loss arising from the drops of condensed water mingled with the steam. In some cases this gain in efficiency is worth the extra cost of the superheater, but, unless intermediate superheaters are used, initial superheat cannot be raised high enough to maintain dryness throughout the major part of expansion without destroying the turbine.

Moderate initial superheat, however, is generally used with some gain



AN ENLARGED PHOTOGRAPH OF A HARDENED STEEL FILE, SHOWING THE DESTRUCTIVE ACTION OF STEAM AT HIGH VELOCITIES.

This file was exposed for 145 hours to the action of a jet of steam at 100 pounds pressure, discharging into a condenser pressure of 1 inch absolute of mercury.

in economy, which in the compound turbine amounts to 1 per cent for every 10° F. of superheat. The second loss, which is from leakage, is present in the compound and the sinuous types but not in the De Laval type. The amount of this loss decreases as the size of the engine increases. It is also chiefly consequent on the coefficient of expansion of metals, which is a bugbear to the turbine designer. If a metal with a much smaller coefficient of expansion than steel and iron could be obtained at a reasonable price and of suitable qualities for the construction of turbine cases, drums, and shafts, a considerable increase of economy could be obtained, as it would allow of smaller working clearances and less leakage. The third loss, from insufficient blade-velocity, is not present to a material extent in the larger compound or sinuous course turbines, but is present, as already explained, to a considerable extent in the single-wheel type.

Reviewing more closely the motion of the steam through the blades of a compound turbine, we see that the portion of its course during which it is traveling at relatively high velocity, and in close proximity to the blades, is short in comparison with the total length of its travel within the turbine. The passageways between the blades constitute virtually jets of rectangular cross section, but having easy curves, and the frictional losses are consequently small. After leaving the blades, it traverses the intervening space in the form of an annular cylinder with a spiral motion, the angle of pitch being about 30° to a plane normal the axis; and, as the succeeding blades are moving in a similar direction to this flow, we see that the velocity with which the steam is cut by their frontal edges is much less—in fact, less than one-half the velocity at which the steam has issued from the previous blades. From this we see how small is the loss due to the cutting of the steam by the frontal edges in the compound turbine, and also how small is the velocity with which drops of water strike the metal of the blades.

This is an important feature.

It has been shown by experiment that if drops of pure water, arising from the condensation of expanding steam, impinge on brass at a greater velocity than about 500 feet per second there results a slow wearing away of the metal. It is very slow, and would require about ten years to erode the surface to a depth of $\frac{1}{32}$ inch. In the compound turbine the striking-velocity is much below this figure, and the preservation of their form and smoothness of surface has been found to be practically indefinite.

It appears that the erosive power of drops of pure water moving at high velocity increases rapidly with the velocity, it may probably be as the square. Experiment has shown that if saturated steam at 100 pounds pressure be allowed to flow through a divergent jet into a

good vacuum, attaining a velocity of about 4,500 feet per second, and allowed to impinge on a stationary brass blade, the blade will be cut through in a few hours, and the hardest steel will be slowly eroded. The action seems to be the result of the intense local pressure from the bombardment of the drops, which may exceed 100 tons.

Owing to the receding velocity of the blades from the blast, and consequently reduced striking velocity, the erosion of the blades in impact turbines is much reduced, and in compound turbines there is complete immunity from such erosion.

It may be asked, how is it that the steam turbine in the larger sizes is more economical in steam per horsepower development than the best triple or quadruple expansion reciprocating engine? The reason is that all large steam turbines are able to take full advantage of the whole expansive energy of the steam, even when expanding to the very attenuated vapor densities produced by the best condensers. It is indeed easy to construct the low-pressure portion of the turbine to deal effectively with the very attenuated vapor, whereas the reciprocating engine, from its nature, can only take full advantage of about two-thirds of the whole range of expansion, and is unable to deal usefully with very low vapor densities—the low-pressure cylinders can not (because of structural difficulties) be made large enough, and the last part of the expansion has to be allowed to run to waste.

The growth in size of the turbine is perhaps interesting. The first practical steam turbine, constructed in 1884, was of 10 horsepower. By 1892 the largest size for driving dynamos had reached 200 horsepower. It has been continuously increasing, and has now reached 12,000 horsepower in one unit driving one alternating dynamo.

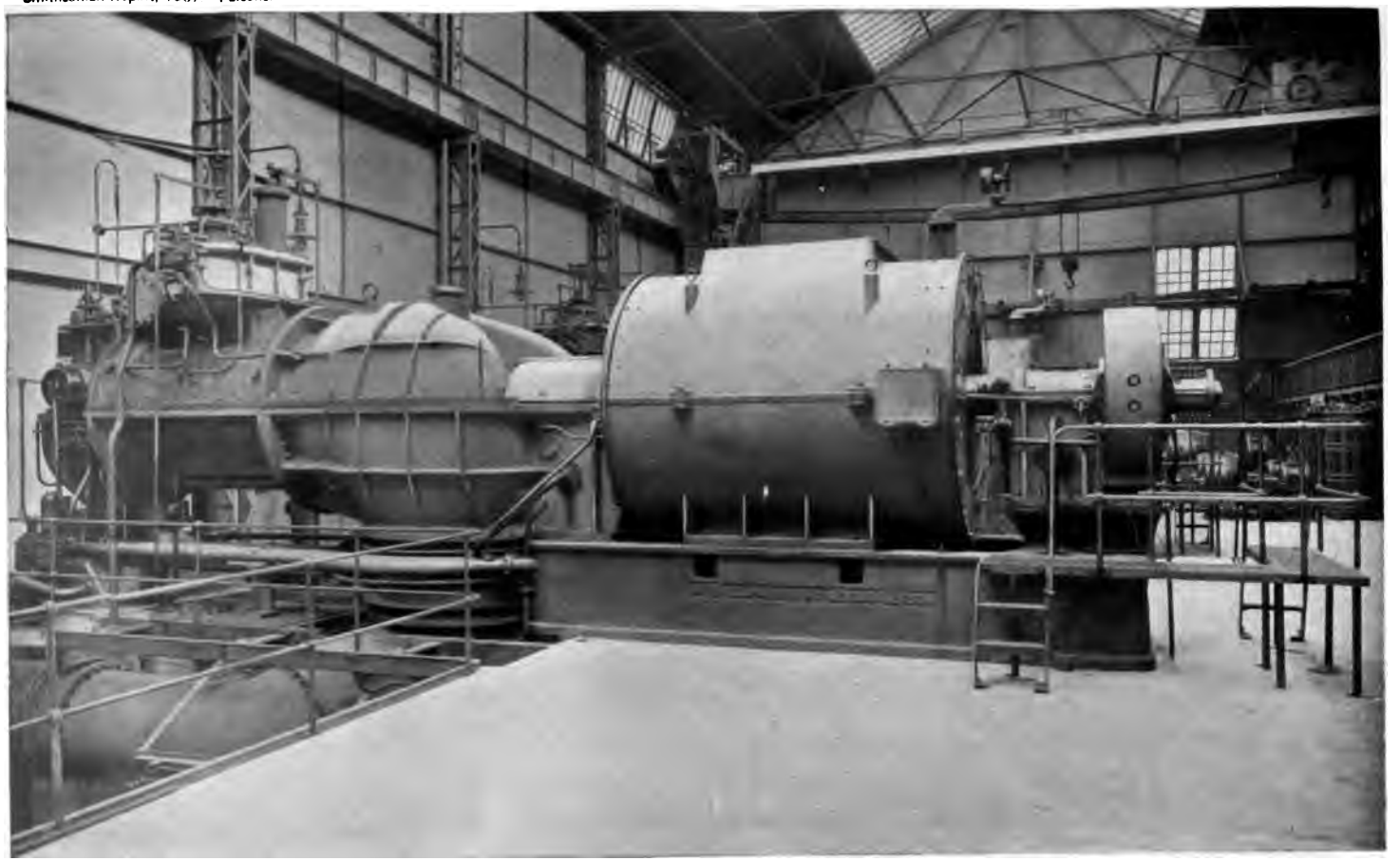
In 1894 the *Turbinia*, of 2,000 I. H. P., was commenced. The diagram (fig. 5) shows her low-pressure and reversing turbine. The L. P. turbine is 3 feet in diameter.

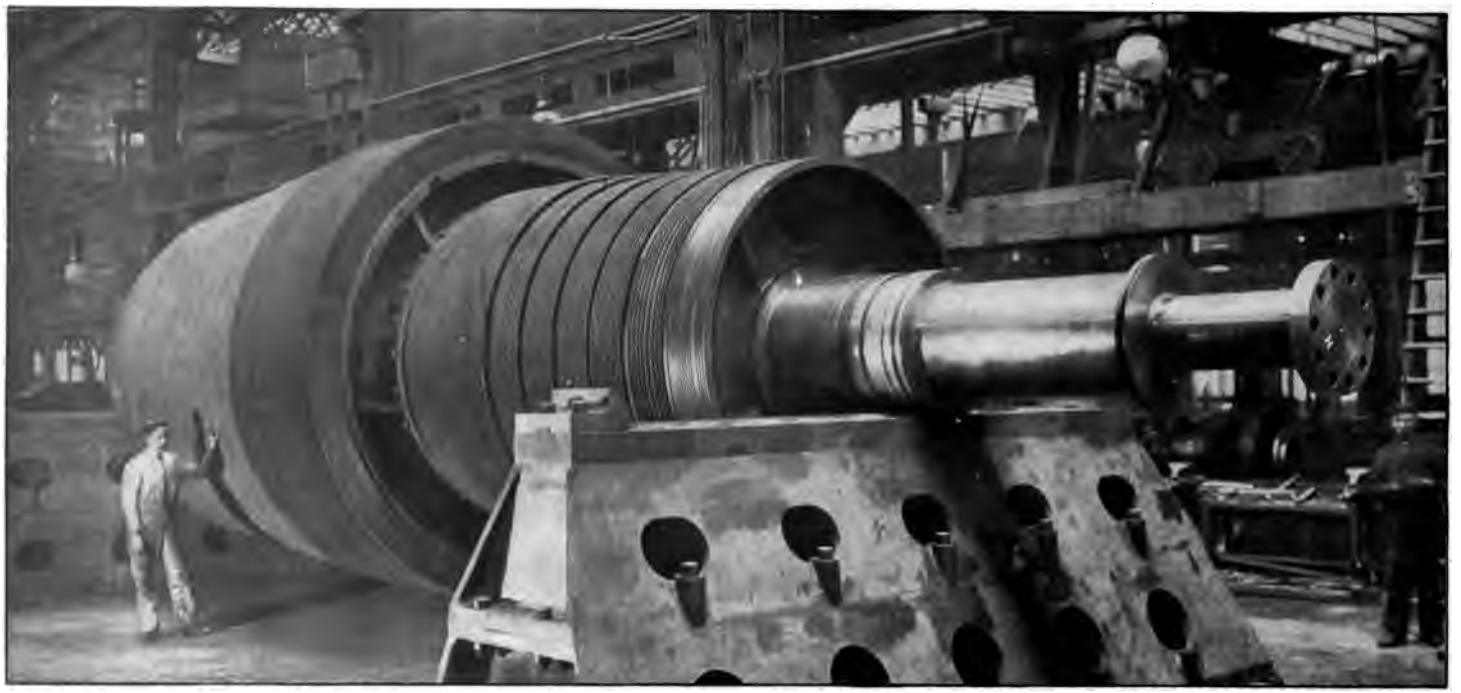
The *King Edward* was built in 1902, 9,300 I. H. P., and the diagram shows one of her L. P. turbines and reversing turbine in one casing, to the same scale.

In 1903 *The Queen*, of 9,000 I. H. P., commenced to ply between Dover and Calais. The diagram shows one of her L. P. and reversing turbines.

In 1905 the Allan liners *Virginian* and *Victorian*, of 12,000 I. H. P., went on service between Liverpool and Canada. The diagram shows one of the L. P. and reversing turbines, which is 10 feet in diameter and 35 feet in length; and in last December the *Carmania*, of 30,000 tons displacement and 20,000 horsepower, commenced to ply between Liverpool and New York. The diagram shows her L. P. turbine, which is 14 feet in diameter.

PLATE III.





SHAFT OF A LARGE MARINE TURBINE.

The application of the turbine to the propulsion of vessels involved some interesting problems. The most important was, how slow could a turbine be made to rotate consistently with the maintenance of its efficiency in steam consumption, and at the same time be of moderate weight and cost?

In the same problem naturally arose the question of how fast could a screw propeller be made to revolve when propelling a vessel of a given size and at a given speed—in other words, when delivering a given propulsive horsepower at a given speed? The first question as to designing a low-speed turbine was solved in 1894 to 1896, by the aid of the accumulation of accurate data from experiments on land turbines; and the modification arrived at in the turbine has been chiefly directed to the splitting of it up into two or three or more turbines in series on the steam, and each working a separate shaft. This splitting up of the turbine results in a twofold advantage. It makes the turbine (which otherwise would be very long) much shorter, and because of being shorter finer clearances and less loss by leakage results, and the whole engine is lightened. A secondary gain, resulting from the division of the power over several separate shafts, arises from the fact that smaller propellers may be used, making higher speeds of rotation admissible, which again acts in lightening and improving the economy of the turbines.

The second question, that of the propeller, was much more difficult. It was not simply the problem of designing a screw with a moderate slip ratio and a moderate loss by skin-friction of the blades in the water, but it was complicated by cavitation, or the hollowing out of the water and the production of vacuous cavities caused by the force of the blades tearing through the water, a phenomenon first noticed by Sir John Thornycroft and Mr. Sidney Barnaby in 1893, and by them named cavitation. This apparatus shows the phenomenon.

[A small tank was shown, with a model of the screw of a cross-channel boat or of an Atlantic turbine liner. It was pointed out that it was very difficult to make the screw cavitate, because it was especially designed not to cavitate; it was, however, made to do so in the tank by removing the atmospheric pressure from the surface of the water above the propeller by the air-pump. The removal of the atmospheric pressure, which helped to keep the water solid, enabled cavitation to be induced at a much lower speed of revolution. In the tank there was a head of about 1½ inches of water above the topmost blades. If the tank had not been exhausted there would have been a head equivalent to 32 feet, plus 1½ inches, plus capillary forces, tending to keep the water solid. Therefore, instead of 1,500 revolutions (the speed of the propeller when serious cavitation was induced), a speed of at least 20,000 revolutions would have been required (because forces

that induce cavitation vary as the square of the surface-speeds of the blades).] Serious cavitation causes an inordinate loss of power, chiefly because it disturbs the steam lines around the propeller blades, and it was proved by this experiment how easy it is to put too much work on a screw. There is a limiting thrust that it will bear, and if we exceed this thrust it will, so to speak, more or less strip its thread in the water and its efficiency will rapidly fall. The solution of the problem, as regards the screw propeller, has therefore resulted in a modification of the proportions of the ordinary propeller, and has lain in the direction of smaller diameters, wider blades, and a slightly finer pitch-ratio, which three slight changes have combined toward higher angular speeds of the propeller without material loss of efficiency.

Let us now turn our attention to the economic results of the steam turbine. In the case of large engines and dynamos that are coming generally into use, for the generation of electricity in this and other countries, of a horsepower of 1,000 to 12,000 and upward, the steam turbine with its accompanying dynamo is found to be cheaper in first cost, running expenses, and fuel than the reciprocating engine and its slow-speed dynamo; and so much is this the case that it seems possible to generate electricity in colliery districts almost, if not quite, as cheaply for electro-chemical purposes as it can be produced at Niagara and some other large centers of water power.

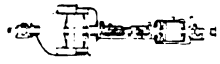
The chief items in which saving has resulted as compared with the reciprocating engine are: The total capital cost of the station is reduced by from 25 per cent to 40 per cent; the reduction in the cost of fuel and boilers is between 10 per cent and 30 per cent, and the consumption of oil is reduced to one-sixth, while the engine-room staff is reduced by 25 per cent to 50 per cent.

As to the economic results of turbine vessels compared with vessels propelled with piston engines, reliable statistics are available.

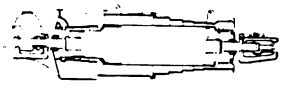
In 1897 the *Turbinia* was found to have an economy in steam per horsepower developed equal to, if not superior to, that of similar vessels propelled by reciprocating engines; and later, in 1903, she was again tried with modified propellers as now generally used which gave a further increase of efficiency of about 10 per cent over the 1897 trials.

In 1902 the first turbine passenger boat, *King Edward*, on the Clyde, was found to consume about 15 per cent less coal than a similar vessel propelled by triple expansion engines and twin screws.

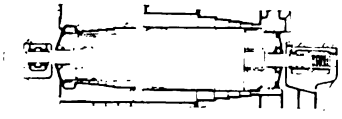
In the diagram (pl. VI) is shown the principal running expenses of the turbine steamer *Queen*, plying between Dover and Calais, compared with three other vessels on the same service. The cost of coal, engine-room staff, and oil are shown in terms of the number of passengers each vessel is capable of carrying.



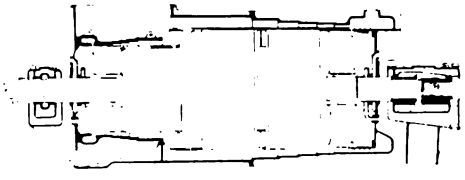
T.S.Y. TURBINIA



T.S.S. KING EDWARD



T.S.S. THE QUEEN



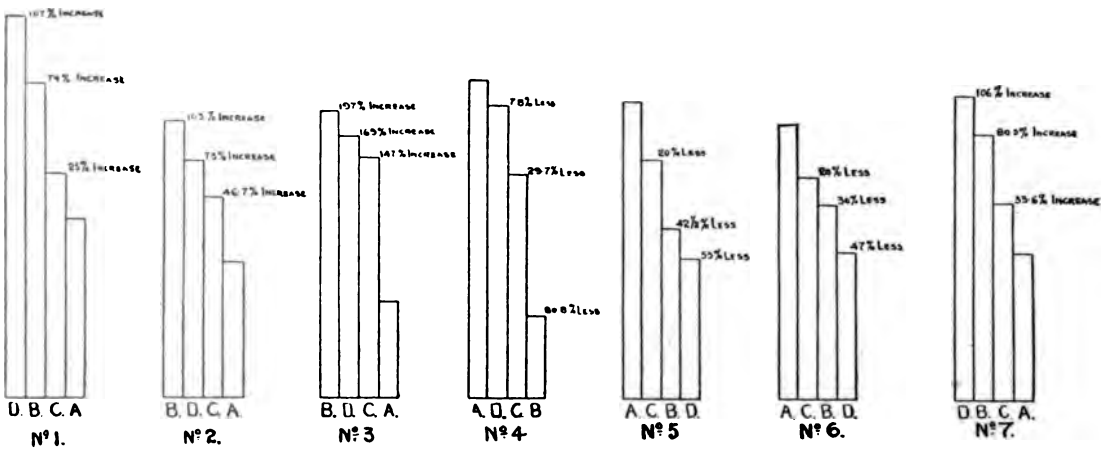
T.S.S. VIRGINIAN

T.S.S. ATLANTIC LINER 200001HP

DIAGRAM, SHOWING INCREASE IN SIZE OF MARINE TURBINES.

DIAGRAM SHEWING COMPARISON OF EARNING POWER OF TURBINE PROPELLED CROSS-CHANNEL STEAMER "THE QUEEN" ON CALAIS AND DOVER ROUTE AS COMPARED WITH THREE OTHER VESSELS FITTED WITH ORDINARY ENGINES ON SAME ROUTE.

Nº 1. POUNDS OF COAL BURNT PER EACH PASSENGER, VESSELS ARE CERTIFIED TO CARRY.
Nº 2. NUMBER OF ENGINE ROOM STAFF PER EACH PASSENGER, VESSELS ARE CERTIFIED TO CARRY.
Nº 3. OIL CONSUMPTION PER DOUBLE TRIP PER EACH PASSENGER. VESSELS ARE CERTIFIED TO CARRY.
Nº 4. NUMBER OF TRIPS MADE IN 6 MONTHS
Nº 5. NUMBER OF PASSENGERS VESSELS ARE CERTIFIED TO CARRY PER TON OF COAL BURNT.
Nº 6. POWER DEVELOPED PER TON OF COAL BURNT PER DOUBLE TRIP AND 24 HOURS.
Nº 7. COST OF COAL, OIL AND E. R. STAFF PER NUMBER OF PASSENGERS VESSELS ARE CERTIFIED TO CARRY.



A. "THE QUEEN"	323 . 43.	21 KNOTS AVERAGE SERVICE SPEED				
B.	324 . 349	18.	0°	0°	0°	0°
C.	280 . 35.	18½	0°	0°	0°	0°
D.	313 . 36.	17½	0°	0°	0°	0°

The statistics of the turbine vessels *Onward* and *Invicta*, on the Boulogne and Folkestone route, have confirmed these results.

The trials of the third-class cruiser *Amethyst*, in 1904, and of her sister vessel the *Topaz*, propelled by triple expansion engines and screws, showed that, at a speed of 11 knots, the consumption of steam was the same in both vessels, but, as the speeds were increased, the turbine vessel gained relatively in economy, and at 18 knots was 15 per cent more economical, and at 20½ knots 31 per cent, and at full speed 36 per cent. Her superior economy in coal enabled her to reach a speed of 23.63 knots, or 1½ knots more than the *Topaz*, on the same coal allowance. The results of the trials also showed that, at a speed of 20 knots, the *Amethyst* could steam about 50 per cent more miles than the *Topaz* on the same quantity of coal.

The experience as regards Atlantic liners is as yet limited to three vessels, the *Virginian*, the *Victorian*, and the *Carmania*. The first two are of the Allan line, 520 feet in length, 15,000 tons displacement, and 12,000 horsepower, with a sea speed of from 16 to 17 knots.

These vessels have been running since the spring of 1905, and the consumption of coal has been estimated to be no more, and probably less, than would have been the case had they been fitted with the most economical engines of ordinary type.

The Cunard liner *Carmania*, of 672 feet in length, 30,000 tons displacement, and 21,000 horsepower, is a sister vessel to the *Caronia*, propelled by quadruple expansion engines of the most economical type, and during the last four months the consumption of coal in the two vessels has been carefully measured, but it is too soon as yet to give the results. However, on the official trials, the turbine vessel exceeded the speed of her sister ship by 1 knot.

Some of the advantages found to exist with turbine propulsion are, that the propellers never race in the heaviest seas, and that, as a consequence, the speed is better maintained under all weather conditions; and the cause of this is to be traced to the smaller diameter of the propellers, wider blades, and deeper immersion. There is also much less vibration.

The tendency of late has been to increase the reversing, or astern, power of turbine vessels to such an extent that, in many cases, the stopping and maneuvering powers have been equal to those of twin screw vessels with reciprocating engines. The starting of turbine vessels is relatively quick, for the torsional force of a turbine, when starting from rest with full steam on, is at least 50 per cent greater than the torque at the usual running speed, because the blades, when running slowly, meet the full blast of the steam instead of moving with it as they do at their usual speeds. With ordinary engines the starting torque does not exceed the torque at full speed. When

maneuvering, turbines can not fail to respond when steam is turned on, for they have no dead centers upon which to stick, as in the reciprocating engine.

From the fact that the faster and larger the vessel the better has been the performance, it seems safe to infer that the two very large and fast Cunarders now building will give satisfactory results, and the same may be expected as regards new turbine construction in ships of war.

The diagram (pl. VII) shows the various steps in the development of the steam turbine as applied to marine propulsion.

The total horsepower in steamships sailing under all flags is at present about 8,000,000. Of this total, about one quarter, or 2,000,000, is in the faster class of ships to which turbines are suitable.

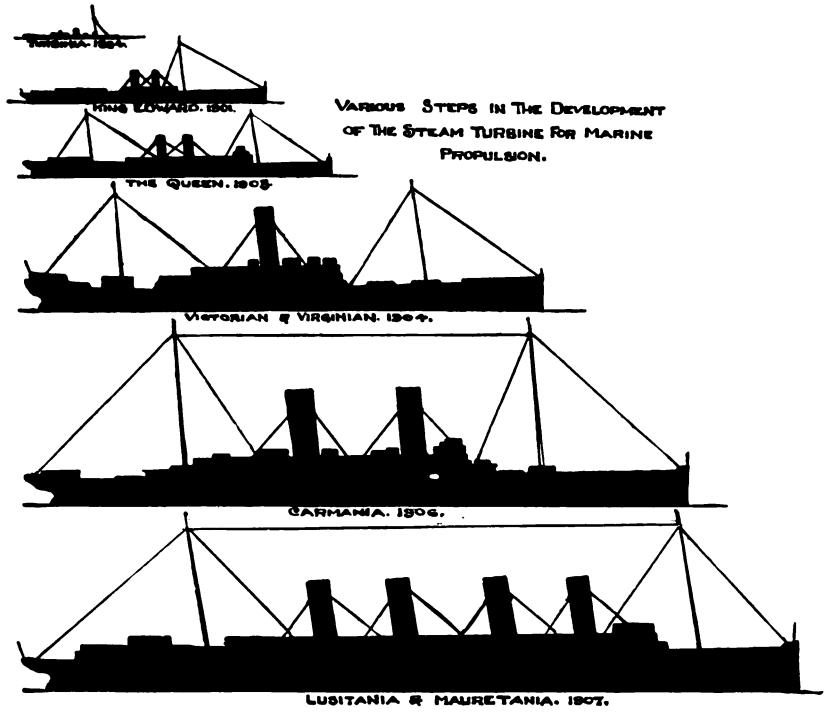
Of the remaining 6,000,000 horsepower, about three to four are in the larger class of ocean tramps, and the remainder in coasting steamers and small river boats, etc.

By a combination of the turbine with the reciprocating engine there seems to be no doubt that the three or four millions horsepower of large ocean tramps may be successfully propelled with a saving of from 15 to 20 per cent in cost of fuel.

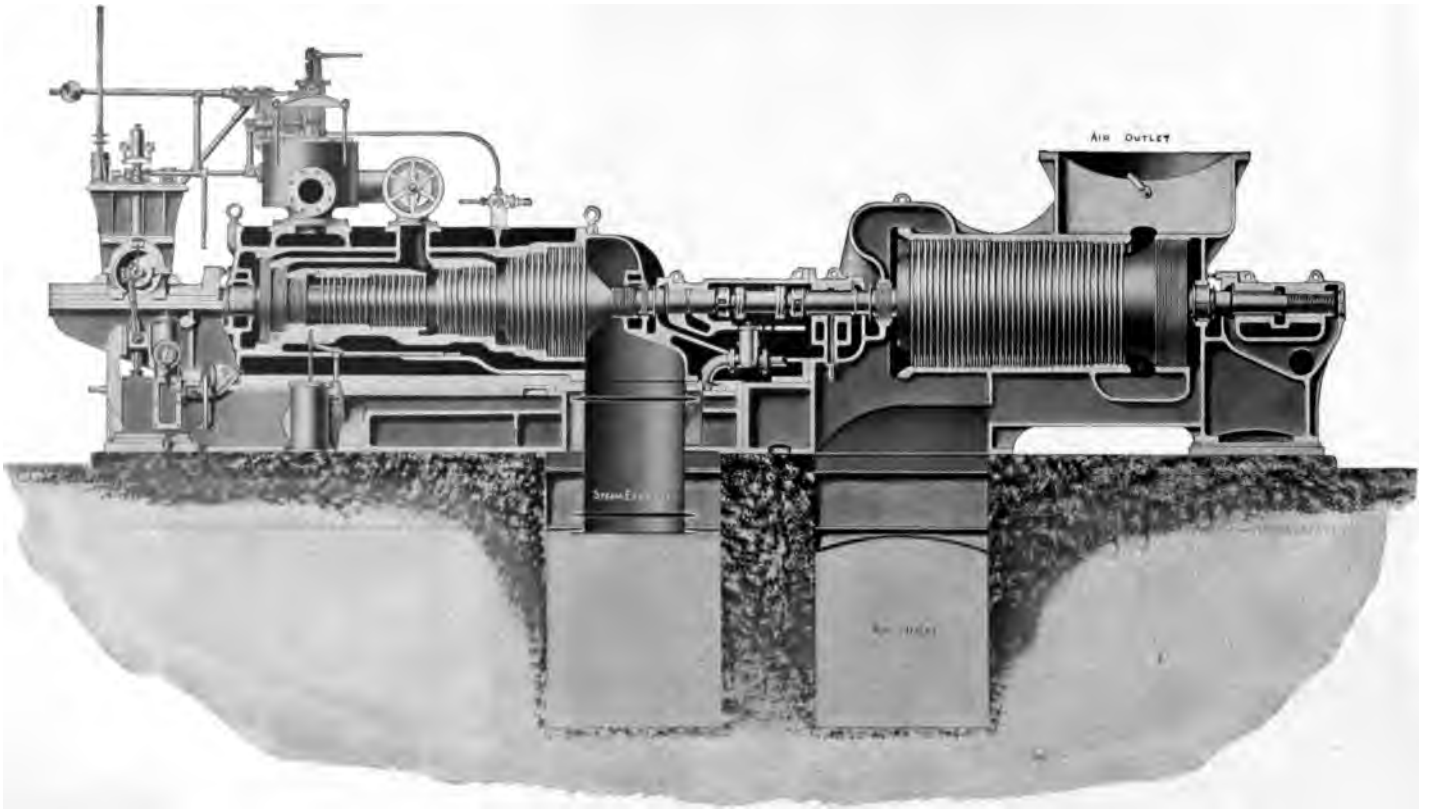
This combination has not yet been applied to any vessel. In it the reciprocating engine first expands the steam from the boiler down to about atmospheric pressure, and then passes on to the turbines, which complete the expansion down to the condenser pressure. The turbine thus utilizes the lower part of the expansion, which the reciprocating engine can not do, and the combination is therefore a good one. For maneuvering or stopping the vessel, either the engine or the turbines, or both, may be used, and there seems to be no doubt that this arrangement will come into vogue for the slower class of vessels of larger size.

Turbines have been applied to other uses within the last ten years. The most important of these are for the working of rotary blowers, air compressors, and water pumps.

The photograph (pl. VIII) shows a cross section through a turbo-blowing engine, capable of compressing 21,000 cubic feet of free air per minute to a pressure of 17 pounds per square inch, which represents about 1,000 horsepower in the air, reckoned in adiabatic compression. In general construction the turbine air-blower portion is similar to a steam turbine. The blades or vanes which propel the air are plano-convex in section, and set in rows at an angle similar to that of the blades of a ship's propeller. Between the rows of moving ades are rows of guide blades inwardly projecting from the case. hese latter are also of plano-convex section, and are set with their



VARIOUS STEPS IN THE DEVELOPMENT OF THE STEAM TURBINE FOR MARINE PROPULSION.



TURBO-BLOWING ENGINE. SECTION THROUGH STEAM AND AIR TURBINE CYLINDERS.

plane surfaces parallel to the axis; and their purpose is to assist the flow and to stop the rotation of the air after being acted on by the moving blades. Each row of moving and fixed blades adds a little to the pressure, and compresses the air gradually along the annular space between the drum and the case. Balance pistons or dummies are provided for balancing the end thrust of the air, as in the steam turbine. The speed of rotation is 3,600 revolutions per minute and the tip velocity of the air blades about 400 feet per second.

NOTE.—Since this lecture was given, many of the predictions contained therein have been realized. The two new large express Cunarders, the *Lusitania* and the *Mauretania*, have given eminently satisfactory results. The steam consumption of the main turbines has been ascertained to be 12¾ pounds per shaft horsepower at full power.

In view of the satisfactory results obtained in the earlier war vessels fitted with turbine machinery for the British Navy, the Admiralty decided to adopt the Parsons turbine exclusively for new construction, from the largest battle ship and cruiser down to and including torpedo boats.

The progress of the Parsons turbine in other countries has also been very noteworthy. In the United States the results attained recently on the trials of the scout *Chester*, equipped with Parsons turbines, when compared with a sister vessel, the *Birmingham*, fitted with reciprocating engines, have shown in favor of the turbines at all speeds. At full speed, on a six hours' trial, the *Chester* obtained a speed of 26.5 knots per hour, as against 24.3 in the *Birmingham*.

In addition to the above, there are in the United States six mercantile vessels now on service (passenger and freight), and five torpedo-boat destroyers are also at present under construction, representing a total horsepower of 110,000 built and under construction.

In Japan there are two large liners now nearing completion, one of which has already completed her official trials, having exceeded the contract speed of 19½ knots by 1 knot. Two small passenger vessels are now on service in Japan. A dispatch boat is also being fitted out for the Japanese Government, and two new passenger vessels and one large liner are at present under construction, representing a total horsepower of 90,000.

In France six large battle ships and three destroyers are under construction of 150,000 horsepower; in Germany excellent results were obtained recently with torpedo-boat destroyer *G. 137*, and at the present time a large and powerful cruiser, as well as a small cruiser and several torpedo-boat destroyers, are under construction, of about 110,000 horsepower; in Italy a cruiser; in Austria a cruiser; and in

this country two scouts are under construction for Brazil. Negotiations are pending for the placing of four large turbine battle ships for Russia.

All the above are fitted with the Parsons type of turbines.

Other countries are also at the present time considering projects for various classes of vessels to be fitted with the Parsons turbine.

The total I. H. P. built and at present under construction of marine turbines is over one and three-quarter millions of horsepower.

On land, in almost every country, the new construction of large generating units are nearly all turbine-driven.

APRIL 6, 1908.

THE DEVELOPMENT OF MECHANICAL COMPOSITION IN PRINTING.[a]

By Prof. A. TURPAIN,
University of Poitiers.

Since the year 1776 efforts have been made to increase the efficiency of the compositor by adding to the ordinary types in the case certain combinations of letters which are frequently repeated. The use of these logotypes makes the type case much more complicated, and instead of increasing the rapidity of composition, diminishes it by causing more errors and consuming more time in finding the type.

It was then sought to accomplish mechanically the several steps in composition. Let us recall these steps: When a line of type is once assembled in the stick, the compositor justifies it by so distributing between the words the free space at the end as to give to the line its proper length. After the type has been used, the workman must return it again to the case.

The first idea of a composing machine seems to have been made public by an Englishman, Church, in 1822. The first practical application of this idea, in accordance with a method devised by Ballanche in 1833, consisted in supplying the case with a keyboard, the manipulation of which freed the characters or type, and these assembled themselves in the composing stick. It was only the operation of picking out the letters that was rendered mechanical; the justification and the distribution remained manual.

By another process, invented a little later, the compositor was enabled to use both hands in picking out the type. The type were thus more rapidly selected and were thrown into a funnel whence they were directed and assembled automatically in the composing stick.

These two processes saved time in the selecting and assembling of the type in the composing stick, but there was no economy of time in the manual processes of justification and distribution.

The keyboard apparatus was imitated and perfected successively by Gobert (1839), by De Klieger (1840), by Youg and Delcambre, who

[a] Translated and abridged, by permission, from the second part of "De la Presse à bras à la Linotype et à l'Électrotypographe" in the Revue Générale des Sciences pures et appliquées, Paris, November 15, 1907.

in 1844 exhibited a machine which, though immediately adopted in the Parisian workshops, was discarded as soon as its disadvantages became apparent.

Since then many composing machines have been invented. Each of these showed some improvement over its predecessor. In this way, by successive improvement, the composing machine has become almost perfect, so that hardly any criticism can be made of the latest model presented, the electrotypograph, which was introduced in 1902, and which was still further improved in 1907 and combined with the teletypograph. Its introduction once more greatly advances economy in typography, and it is likely to increase typographical efficiency almost

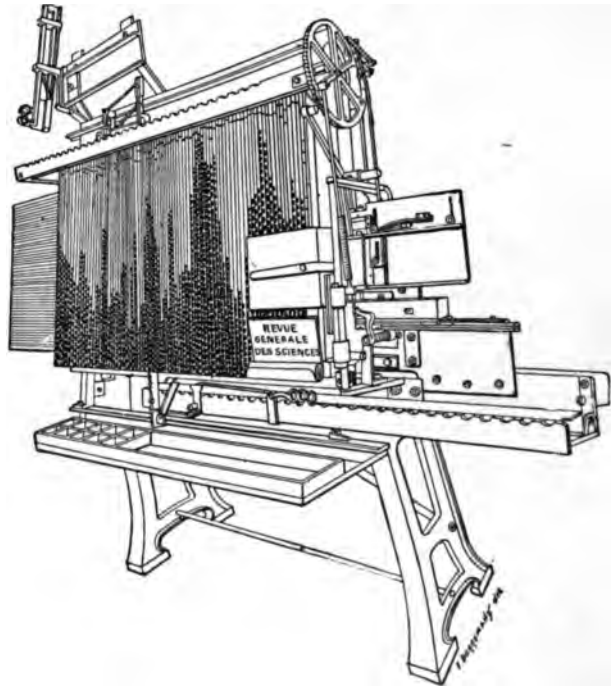


FIG. 1.—Lagerman composing and distributing machine.

infinitely. With its aid the printer need not fear to undertake orders requiring unheard-of speed and numbers of impressions.

Before describing the electrotypograph, we will review the earlier forms of composing machines in order to understand it more clearly. Only the most characteristic of these will be described.

MACHINES WITH MOVABLE CHARACTERS.

The composing machines first to be considered, the Kastenbeim, Thorne, Simplex, Lagerman (1885), Paige, Desjardins (1898), Caldoli (1900), etc., form a class accomplishing composition by mov-

able type which they afterwards distribute, often by mechanisms independent of those of composition. Most of these machines compose by the operation of a keyboard, freeing the type from the channels of a magazine, but only a few of them justify the line.

Lagerman machine.—The Lagerman machine (fig. 1) is very simple in its arrangement and uses finger-stalls instead of a keyboard both in composing and distributing. The justification of the line is automatic. The machine separates the words equally by two 3-em spaces, making the line either the proper length or too long. If too long, the justifying mechanism then does its work by replacing a 3-em space by a 4-em space, thus reducing the line by one-twelfth of a quad between each word. This process is repeated till justification is completed.

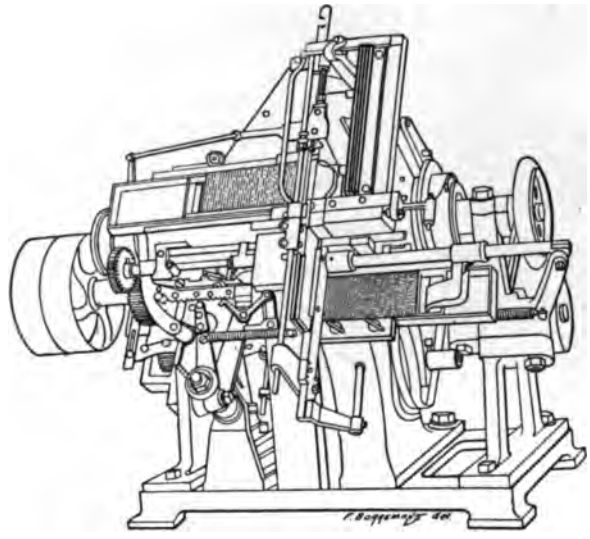


FIG. 2.—Desjardins justifying machine.

Desjardins machine.—The Desjardins machine (fig. 2) is a justifying mechanism used in America in connection with composing machines. The lines of the galley are successively raised by the machine, which counts the number of spaces by means of little copper strips projecting above the type which have been inserted for that purpose. Another part of the machine *feels*, so to speak, the space remaining at the end of the line, adds it to the total of the counted spaces, and divides the whole by this number of spaces. By the combination of three sizes of spaces (17, 24, and 31 thousandths of an inch), which it keeps in reserve, the machine forms and inserts between the words the space which it has thus automatically measured. If there be a remainder after the division, an ingenious arrangement of the machine reserves it, and adds it to the last space of the line. The working of the calculating mechanism takes less than a second.

Calendoli machine.—We will not complete this brief examination of the first type of composing machines without a word concerning the Calendoli machine (fig. 3), which is solely a composing machine. It composes with the speed of a typewriter, that is to say 15,000 ems or characters per hour. The type, cast in a special shape, issues from 90 type-bar magazines consisting of mushroom rails on which the type is threaded. A workman behind the machine recharges the magazines as they are emptied. An inclined cylinder provided with

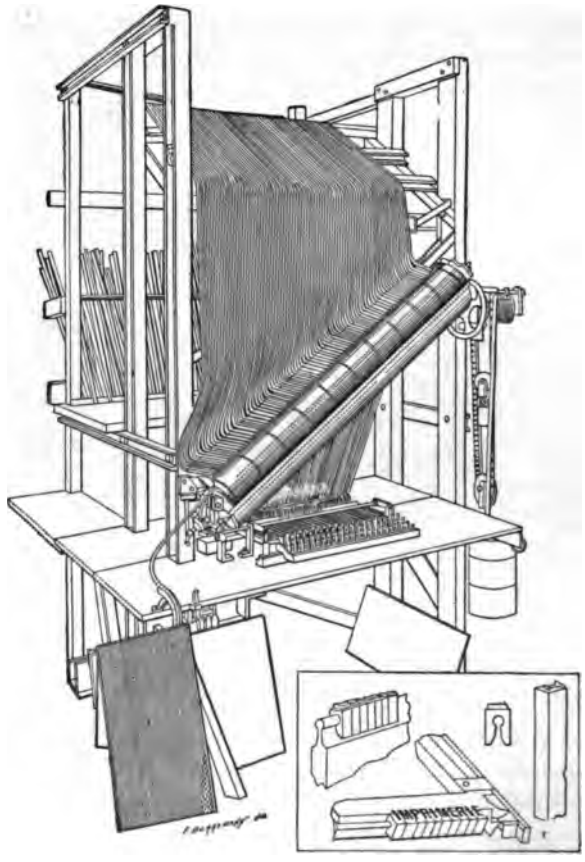


FIG. 3.—Calendoli composing machine.

rails along its long dimension receives each type as the operator frees it by the manipulation of a keyboard. The type is thus arranged in the galley by its own weight. The machine neither justifies nor distributes. It is therefore necessary to combine it with a justifying and distributing apparatus, or with a casting machine. Composition is effected so rapidly as to allow comparatively more time to be given to the justification and distribution. One could, moreover, combine a Desjardins machine of the type already described with the Calendoli machine.

CASTING MACHINES.

A second class of composing machines marks an interesting improvement over the first in that the distribution of type is obviated. These are *casting machines*. They thus answer the criticism made against their predecessors, the necessity of special type with particular notches (the Lagerman notch, the Calendoli groove, for example), permitting the seizure of the type by the parts of the machine. The casting machines should be separated into two distinct classes.

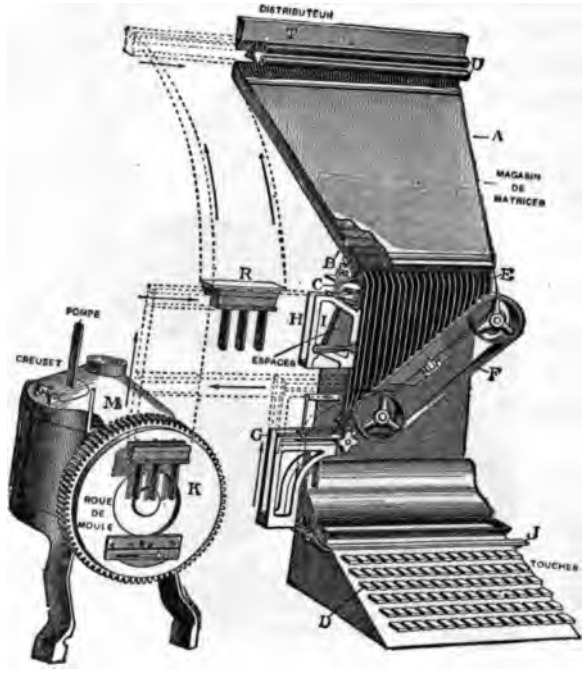


FIG. 4.—Diagram showing operation of the linotype machine.

(A) MACHINES FOR CASTING THE LINE.

In the first class we place the machines that produce solid lines. The operator plays on the keyboard and composes the line in copper matrices. It is justified by copper wedges forced between the words. A jet of molten lead flows into a mold the bottom of which is formed by the matrices, and a solid line of type is thus made. We find here the system of stereotyping invented by Herhan in 1801 applied to a single line of characters. In the first class of casting machines is included the typograph (pl. 1) of Rogers, the, monoline (pl. 1) of Scudder, and finally the linotype of Mergenthaler, which is the oldest and in France one of the best known machines for forming a solid line (figs. 4–8).

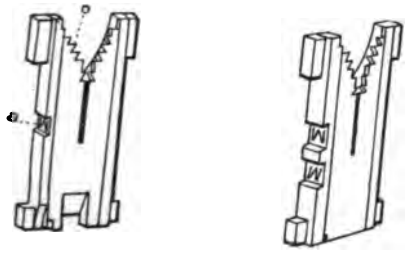
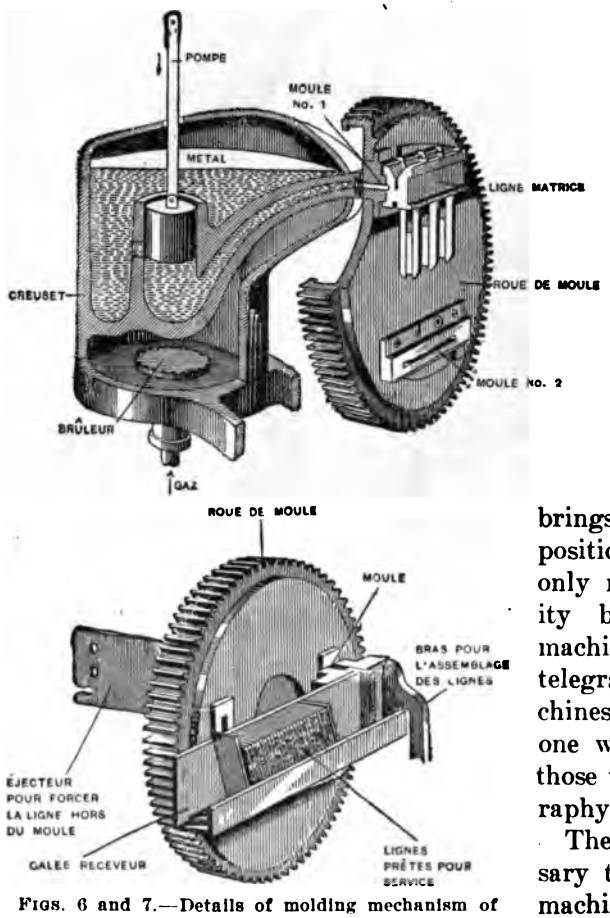


FIG. 5.—Linotype matrices.

I do not mean to say that no distributing function is employed in these casting machines, for the matrices must be returned to their

respective chambers after the line is cast. In the linotype machine this is effected by a V-shaped distribution bar the sides of which have a series of grooves that engage teeth corresponding to them on the sides of each matrix. The arrangement of the teeth varies on each matrix and the position of the grooves likewise varies on the distributing bar above the compartments of the magazine. The apparatus is so designed that as the matrix is pushed along the distributing bar, when it reaches its proper channel, nothing prevents it from dropping into its compartment in the magazine. We here find something analogous to the "feeler" which, in Baudot's telegraphic machine, by means of a combination of five levers, prints each letter at the moment when the type wheel carrying the letter brings it into a vertical position. This is not the only mechanical similarity between composing machines and multiple telegraphs, for few machines are more involved one with the other than those used in rapid telegraphy and typography.



FIGS. 6 and 7.—Details of molding mechanism of the linotype.

The motive force necessary to work a linotype machine is less than half a horsepower. The speed of composition is normally 5,000 ems or characters per hour, and may attain, with skilled operators, 6,000 to 7,000 ems per hour.

A single operator manipulates the machine. One caretaker can clean and keep in order five or six machines. On the other hand, corrections necessitate the complete making over of the line, and, as in similar machines, the mental strain on the operator is incomparably greater than that felt by the hand compositor. Not only must he read

THE TYPOGRAPH.

THE MONOLINE.

MACHINES FOR COMPOSING A CAST LINE.

THE ROTOTYPE.

a

b

THE MONOTYPE.

(*a*) Typewriter and perforating machine. (*b*) Casting machine.

THE ROTOTYPE AND MONOTYPE MACHINES.

the manuscript five or six times more quickly than the hand compositor, but he must also watch both the keyboard and the melting furnace.

Besides the inconveniences of this first class of casting machine, such as the making over of the whole line for the least correction, there is another objection. Printers complain that in casting the monolines, the typographs, and the linotypes the metal does not flow into the shallow matrices at a temperature low enough to give a good face and to print a very clear impression. Furthermore, the metal

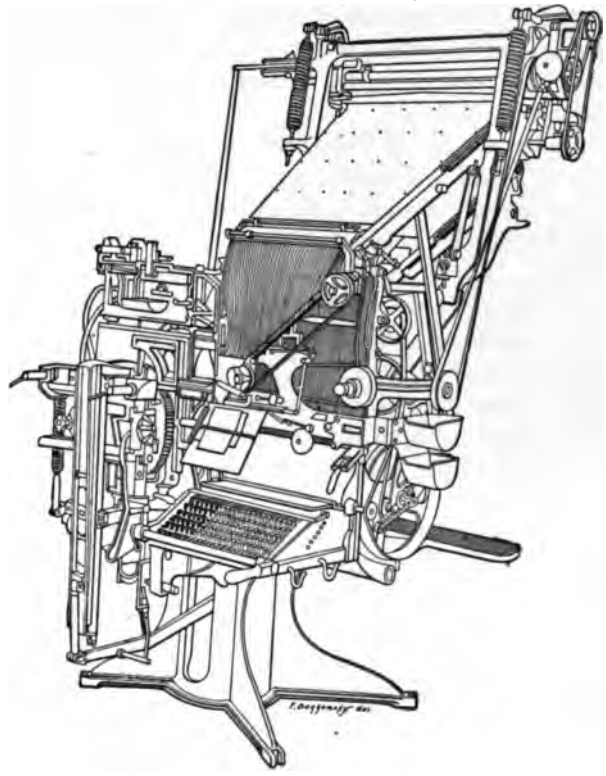


FIG. 8.—General view of the linotype machine.

lines are often hollow and may be crushed in putting them in the form for presswork.

The rototype (pl. II), invented very recently by an Austrian, M. Schimmel, likewise produces a line cast as a single block. A large wheel carries four collectors placed at right angles. The collector, I, at the extremity of the horizontal diameter of the wheel in the position of departure, receives the row of matrices forming a line. It is carried below the diameter of the wheel where the line is justified, while the second collector, II, receives in its turn a row of matrices.

The justification is no less ingenious. The lines are composed with elastic spaces and are always a little too long. In shortening the line to the required length, each space is contracted, which is made possible by its compressibility. A quarter turn of the wheel brings the justified line to the casting pot. At the same time collector I receives the cast line, the line in collector II is justified, and collector III receives the series of matrices forming a third line. Finally a last quarter of a turn carries the matrices of the first composed line, previously free from the cast line, to the height of the vertical diameter, where they are distributed in the magazine for further composition. The same successive rotation by a quarter of a turn continues, so that when the machine is in operation, while one line is being composed, the preceding one is justified, the one before that is cast, and the matrices of the previous one distributed.

One of the advantages of the rototype is that the melting pot is placed as far as possible from the operator.

The distribution of matrices is simplified by the use of disks analogous to the die of the electrotypograph, but with ten characters instead of three. Thus, on the circumference of the same disk are associated the matrices of letters of the same thickness, capitals G, M, W, . . . small straight letters, i, l, t, !, . . . and small letters of equal thickness, d, c, e, . . . All disks of the same thickness and with the same letters have the same compartment in the magazine. The machine in freeing them threads them around an axle, to which they become attached only when the desired letter has reached the vertical position.

The rototype can compose 6,000 characters per hour and requires only one-eighth of a horsepower for its operation. * * *

The 1907 model of the rototype has no wheel, properly speaking, but has three arms with only three matrix carriers. These are hinged, and thus simplify corrections. The keyboard of the latest model has 100 keys, with 400 roman and 400 italic matrices. The face of the character is deeper than that of the linotype. Finally, the machine, which weighs about 450 kilograms, occupies only a small space, being 1.40 m. in length, 0.85 m. in width, and 1.50 m. in height.

(B) Machines Casting Single Type.

To avoid the disadvantages of slug-casting machines, a second class has been devised. These machines compose with movable characters cast to measure and assembled in justified lines by means of spaces cast to measure with dimensions calculated in advance. This machine performs the same work as the compositor at the case, omitting none of the successive steps, but enormously increasing the

speed of composition. As usual, these machines, certain types of which have attained the highest degree of perfection, apply the principle of the division of labor. Two absolutely distinct machines are associated: First, *a composing machine* with a keyboard; that is, a writing machine which perforates a ribbon to be transferred to the casting machine; second, *a casting machine*, which receives the perforated ribbon from the composing machine, casts the successive letters as well as the spaces, and assembles them in justified lines.

The principle of these machines was conceived in 1872 by an American named Westcott. One can not help comparing the principle followed in both of these machines, namely, the perforated ribbon, with that of the Wheatstone automatic telegraph, invented by the physicist Wheatstone in 1859.

The first two types in this class are the Goodson graphotype and the Lanston monotype (pl. II).

The graphotype, to solve the problem which we have just mentioned, employs more than 650 contacts of mercury and 60 electromagnets. There are, therefore, opportunities for inaccuracies in its operation. Furthermore, the keyboard operator must, at the end of each line, read two numbers on the tables or dials, and then choose in a definite order a certain number of special keys which control the justification perforations. Each movement of the block which carries the matrices is followed by a sudden stop, and as the block weighs 3 kilograms and performs 20,000 movements per hour, this is a source of wear and tear on the machine.

The monotype is based on the same principle. The manipulation of the keyboard of the perforating machine produces a ribbon, perforated with letters clear like those of a typewriter, thus allowing an inspection of the composition. Justification, as in the graphotype, necessitates a reading and the choice of a lever; the speed of composition can not, therefore, attain that of the ordinary typewriter.

The perforated ribbon is then transferred to the casting machine, where it is drawn between a series of holes which follow the line of perforations and a groove through which comes a jet of compressed air. This jet of air passes through the perforations and actuates a mechanism which frees the matrix corresponding to the perforated character and carries it under the melting pot containing type metal kept in fusion by a gas jet. A drop of molten metal runs into the matrix and thus forms the type which, cooling almost immediately, is deposited in a channel where the entire line of type is assembled. Corrections are easily made, as each type is a separate piece. Nevertheless, the whole process is a delicate one on account of the application of compressed air.

THE ELECTROTYPOGRAPH.

The electrotypograph, designed by the Hungarian inventors, Meray and Rozar, is incontestably superior to its predecessors. Justification is absolutely automatic. The keyboard operator, without making any reading, manipulates a single lever at the end of each line. One can therefore attain the speed of a typewriter in composition, or about 15,000 characters per hour.

(1) *Composing machine.*—The composing machine consists of a Williams typewriter, a perforator, and a calculator. The typewriter

FIG. 9. The composing machine of the electrotypograph.

furnished a copy of the composition, which can be corrected, thus giving a proof *before casting*. The perforator makes a row of holes in a paper ribbon or band. There are eight series of these holes arranged in rows across the band (fig. 10); let us designate them by the numbers 1, 2, 3, 4, 5, 0, 6, and 7. The perforations by the series 0 are continuous and are for the purpose of advancing the band. The combinations of perforations 1, 2, 3, 4, 5 correspond to the series of small or lower-case letters, just as do the combinations of the five

levers of the manipulator in the Baudot telegraph. If to these combinations the perforation 7 is added, the letter becomes a capital. If the perforation 6 is joined to one of the combinations 1, 2, 3, 4, and 5, a punctuation mark is obtained. Thus the perforations 3 and 4 correspond to the small letter *b;* the perforations 3, 4, and 7 to the capital B, and the same perforations 3 and 4 with 6 indicate the exclamation mark (!).

As the band is perforated, the calculating device registers the thickness of the characters as they will be finally cast, the thickness being measured in tenths of a millimeter. The spaces between the words are estimated by the calculator at the normal value of 15 tenths of a millimeter. These spaces are added up as the line is written. At the end of the line all the operator has to do is to press the justification key and the apparatus (1) calculates the difference between the total of the spaces and the desired length of the line, (2) divides this difference by the number of the spaces, and (3) inscribes on the band as a special perforation the resulting correction for each space. These corrections indicate either an addition to the normal spacing of 15 tenths of a millimeter or a subtraction from that spacing. Three successive perforations are produced by the single manipulation of the justification key; the first two relating to the operation of justification and the third indicating the end of the line.

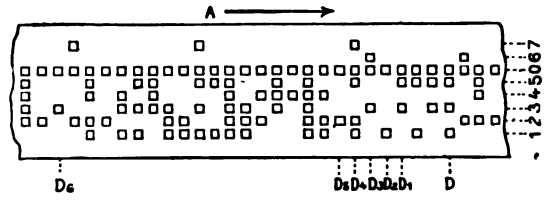


FIG. 10.—Perforated band furnished by the composing machine of the electrotypograph.

The result of the calculation for justification, inscribed on the band, indicates how many tenths of a millimeter more or less are needed for each normal space, 15 tenths of a millimeter, to obtain the justified line.

When we pass from one font to another, from the roman to the italic for example, it is only necessary to substitute in the computing apparatus a special cylinder which is easily removed. No change is needed in the justification apparatus.

Theory of justification.—The operator is warned by a bell when there remains only 5 millimeters of the line to be filled; he can, however, go 5 millimeters beyond the prescribed length of the line. He therefore has a latitude of 10 millimeters and can terminate at the end of a word or a syllable.

Let l be the length of the prescribed line, λ the length of the line as made by the operator with the normal spaces of 15 tenths of a millimeter each, and n the number of spaces in the line

The difference between the length of the line as it must be justified and its length as actually made is the difference between l and λ; l may be either greater or less than λ.

Let us say that the difference between l and λ, divided by n, is $\pm q$, and suppose first that this division gives a quotient q without remainder. Each space in the line would be increased (+) or diminished (—) by the amount q according to its sign. These calculations are performed automatically by the machine, and it is the value of q

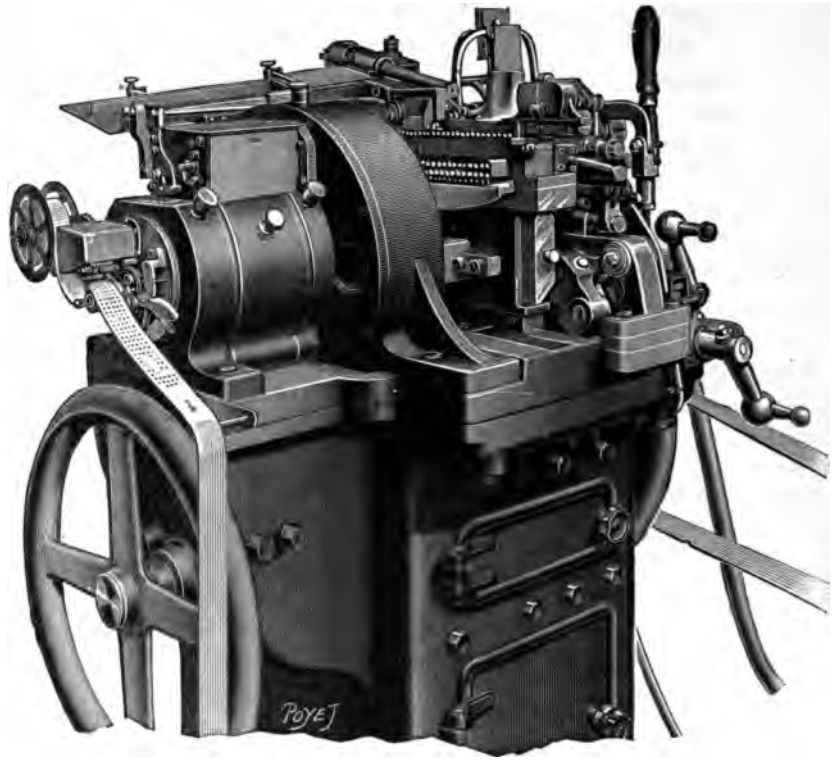


FIG. 11.—The casting machine of the electrotypograph.

that is indicated by perforations on the ribbon when the justification lever is operated.

Let us suppose, however, that the difference between l and λ, divided by n, gives the remainder v, which is generally the case, as the machine can not calculate the spaces closer than a tenth of a millimeter. In this case besides the correction q, which affects each space in the line, the v first spaces receive a supplementary correction of one-tenth of a millimeter, until the remainder v is used up.

Proof before casting.—The proof copy, furnished by the writing machine working in the ordinary way, may be corrected even before the type is cast. Corrections which require the resetting of one or

several lines are made by cutting the defective part out of the ribbon and substituting a piece of corrected ribbon. Corrections of one or two letters are made in the line by the ordinary nippers after it is cast.

Keyboard.—In the latest model of the electrotypograph (1907) the keyboard has in all 97 keys, 90 of which, by means of a shift key, allow the writing of 180 characters. One key is reserved for justification; its manipulation is entirely mechanical, the operator having only to press it at the end of each line without any preliminary reading. One key is added for the feeding holes, 0, in the ribbon; another large key for variable spaces and finally four keys for the fixed spaces, 1 em, 2 em, etc.

(2) *Casting machine.*—The perforated ribbon or band, taken from the composing machine, is transferred to the casting machine (fig. 11). These two machines are entirely independent. The perforated bands can be composed at leisure and the type cast as needed. This is not one of the least advantages of machines casting movable characters, and as the electrotypograph is a perfect example of this class of machines, its superiority is particularly marked. It permits the printing of a limited number of copies of a work, and since the perforated bands are preserved, a new edition may be printed by again casting the type. Thus as many successive editions as desired may be produced without new composition, or the storage of a considerable stock of type or stereotype plates.

FIG. 12.—Matrix disk of the electrotypograph.

Thus, by a process more economical than stereotyping, one of the desires of the bookseller is realized. One large printing office in Saxony before the Revolution, and before the invention of stereotyping, was able to furnish books at prices much lower than its rivals by preserving the composition in storage and printing in proportion to the demand. But at the price of how much inactive capital!

The perforated band of the electrotypograph of MM. Meray and Rozar passes through the casting machine in an opposite direction from its make-up. The lines are thus cast letter by letter in an opposite direction, from right to left. In this way, the machine *knows, before commencing a line*, the exact value of the spaces it must furnish. This is another manifest advantage of this machine.

The molten metal is injected into a mold, one end of which is closed by an indented matrix, where the face of the character is formed. A movable carriage holds 29 disks on the facets of which are cut the matrices. Each disk has three facets at angles of 45° (fig. 12). The middle facet bears a small or lower-case letter, the one to the left the capital or upper-case of the same letter, and the one

to the right the corresponding sign. The choice of the disk is made according to the combination of the perforations on the ribbon, in a manner analogous to that of the combiner and feelers of the Baudot telegraph. The spaces are cast in the same way as the letters, the mold being closed by a disk without a matrix. The thickness of the space is determined by the slide valve of the mold, the heel of which strikes against the justification apparatus. This mechanism consists of four disks mounted on the same axle, forming a combination which expands or contracts according to the result of the calculation of justification. When a line is finished, it is pushed automatically into a galley. The machine then stops casting for three turns, while the justification apparatus receives the measurement corresponding to the spaces to be furnished to the line which is to be composed, a dimension indicated by the perforations D_3, D_4 (fig. 10). These perforations are reserved for justification at the end of each line. The first row, D_3 (fig. 10), indicates by the position of its perforation the number of spaces at the beginning of the line which should receive the supplementary correction of one-tenth of a millimeter; the second row, D_4, indicates, by adding the values determined by the position of its perforations from 1 to 5 (perforation 5 representing the value of 10), the number of tenths of a millimeter to be added or subtracted to all the spaces of the line.

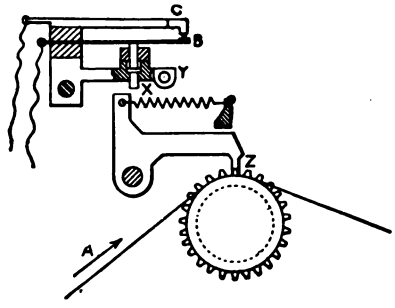


FIG. 13.—Diagram of registering apparatus in the casting machine of the electrotypograph.

Let us take for example the band shown in fig. 10. The perforations of series 6 represent subtraction, those of 7 addition.

In D_3 we find perforations 3 and 6 indicating that it is necessary to subtract (perforation 6) one-tenth of a millimeter from each of the first three (perforation 3) spaces of the line.

In D_4 we find perforations 1, 2, 5, and 7, showing that it is necessary to add (perforation 7) to each normal space of 15 tenths of a millimeter, a number of tenths of a millimeter 1+2+10 (perforation 5 having the value of 10), that is 13 tenths of a millimeter. Thus in this line, the first three spaces will be cast with a thickness of 15+13—1, or 27 tenths of a millimeter, and all others with a thickness of 15+13, or 28 tenths of a millimeter.

The perforated strip, A (fig. 13), is carried along by a cogwheel whose teeth engage the perforations of the series 0.

The machine makes 90 turns a minute, advancing the band one ision and casting a character at each turn. The movement of

the wheel is very rapid, lasting scarcely one-fifteenth of a second, the band then remains stationary for nine-fifteenths of a second, the whole turn thus taking ten-fifteenths, or two-thirds of a second. While the band is motionless, seven letters, Z (fig. 13), press against the paper, and those that find perforations make contacts closing electric circuits. This is accomplished by the heel of the lever Z, which raises the piston X, pressing the spring B against C and making the contact.

The electrotypograph is controlled by electricity, hence its name, but its inventors used only very simple electrical arrangements, with weak electro-magnets requiring a current of low tension. In contrast to the Goodson graphotype, the perforating machine of the electrotypograph does not use electricity. All its functions are purely mechanical, without compressed air or electric current. Mechanism was substituted because of the inaccuracy of electric or other contacts established by the play of a keyboard, which produces variable pressure in rapid work. In their casting machine, on the contrary, the inventors of the electrotypograph made a very judicious use of electric power; there the mechanical movement of the parts assures perfect contacts. Unlike the graphotype, the electrotypograph uses only 15 (instead of 60) electro-magnets. These are all of the same strength and have a resistance of 100 ohms, using a current of only 0.1 ampere under a potential of 10 volts. There is never but one electro-magnet in action at a time in the machine, and the duration of its excitement is less than one-twentieth of a second. In the most recent machines, a single electro-magnet automatically stops the machine in case of damage or trouble in operation arising from the negligence of the operator. Thus, the machine stops when the end of the perforated ribbon is reached. In this way the machine is automatic to such an extent that one workman can easily watch two machines * * *.

IMPROVEMENTS AND RESULTS OF THE ELECTROTYPOGRAPH.

Since the trials made by the journal Le Temps with the 1902 model of the electrotypograph—trials which were attended with complete success—important improvements have been made in the mechanism of the machine, and it has now advanced beyond the experimental stage.

The new model has many and very important improvements over the 1902 model, among which are: A mechanism permitting the casting at will of high or low spaces; the addition of letters with a projecting face like V in italics; simplified construction in the justifica-

tion mechanism in the casting machine, allowing the use of a single electro-magnet in place of eight; an increase in the width of the galley, permitting the production of lines 40 pica ems (180 mm.) in length; an arrangement for the automatic feeding of the melting pot; an improved composing machine in which all the parts are easily accessible, and which furnishes a band on which each letter is printed below its corresponding perforation; and finally a change in the casting machine permitting the casting to commence with the first letter written, thus making the combination of the two machines possible.

The latest improvement is valuable in the composition of newspapers. A considerable loss of time is avoided, as it is no longer necessary to have all the lines of an article cast before putting it in page form. The casting machine only has to wait for the perforation of a single line before engaging the band; then it deciphers the justification perforations to regulate the spaces, and casts the line following the band letter by letter as fast as it is produced.

Plate III represents the 1907 model of the electrotypograph. We see in "a" a portion of the band corresponding to a line, attached in the casting machine so as to allow the combination of the two machines. The composition may thus commence with the first perforated letter.

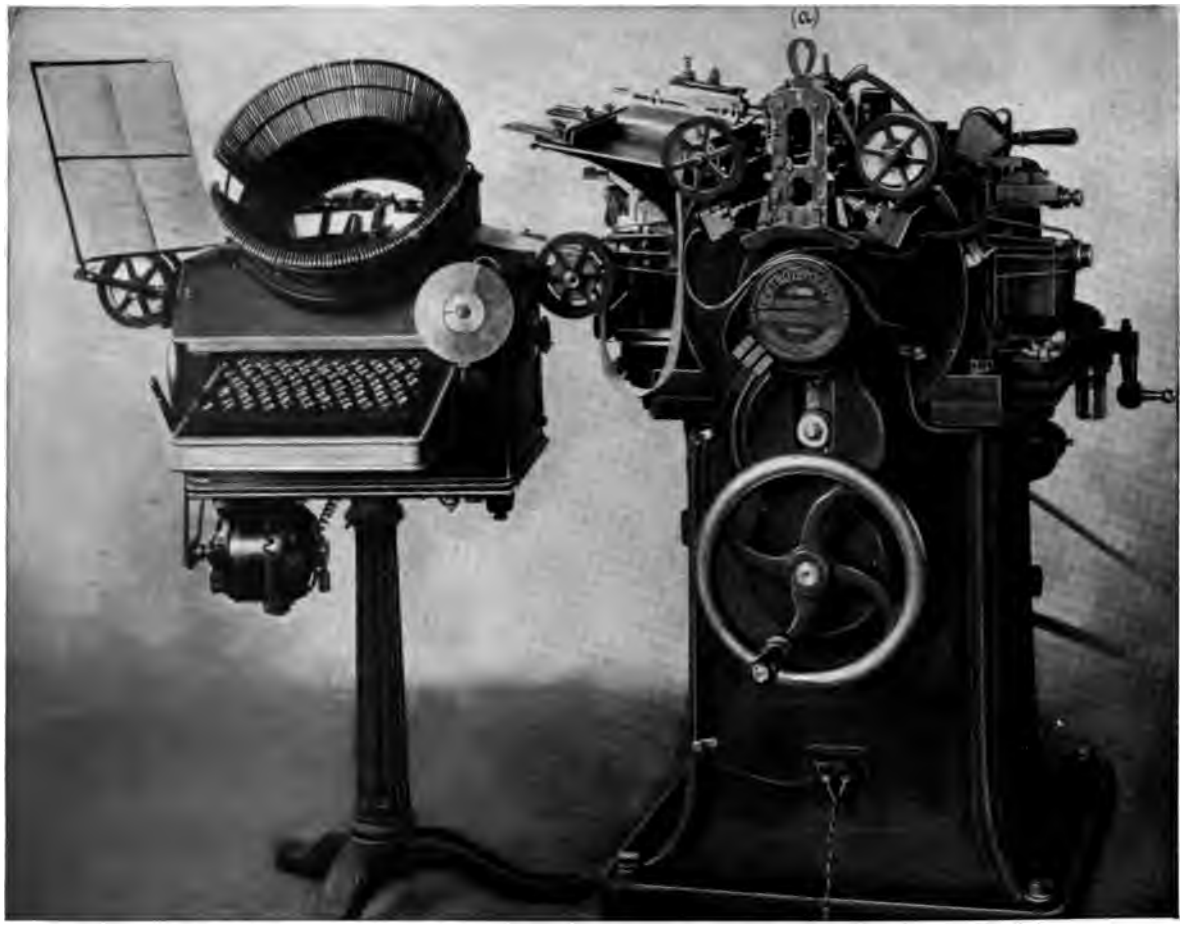
The electrotypograph has the following advantages over previous composing machines:

1. The movable characters facilitate the corrections indicated by the reading of the copy sheet furnished by the composing machine.

2. The matrices have a deep face, and thus give a clearer impression. They are few in number, making it possible to replace them at small cost. Thorough tests have demonstrated that the machine composes in 5-point type with the same clearness as with the largest characters.

3. The division of the apparatus into two machines makes the learning of its operation easier, and permits a more general use of it, since even small printing offices can purchase the composing machine at a slight cost and send the perforated bands to shops possessing casting machines. The perforated band thus takes the place of the stereotype plate, but is less cumbersome, entails no idle capital, and can be passed about one hundred times through the casting machine. During the slack season and at other times when not in use, the casting machine may be employed to manufacture type.

But there is still more to be said. An apparatus analogous to the Baudot telegraph called the teletypograph has been designed which makes possible the telegraphic transmission of the band perforated by the electrotypograph. A single band produced by the writing


(a)

machine can be reproduced at a distance by telegraphy, giving an exact reproduction, which can be placed on the casting machine and will furnish immediately the composed and justified text ready to be put on the press. In this way a newspaper article sent from Paris in this form can be reproduced ready to be printed in various distant cities, and it is possible for large newspapers to have country editions without increase in expense and without delay, a great step forward in journalism.

Finally, on account of its mathematically perfect justification and its ease of correction, the electrotypograph stands forth as an apparatus suitable for every sort of delicate work.

SOME FACTS AND PROBLEMS BEARING ON ELECTRIC TRUNK-LINE OPERATION.[a]

By FRANK J. SPRAGUE.

One of the foremost railroad men of this country, in discussing the needs of the present railway system a few months ago, said:

> The only relief which can be obtained through economies of physical operation must come through the outlay of enormous amounts of money such as would be involved in a general electrification or a change in gauge.

At the April meeting of the Buffalo Chamber of Commerce another eminent railroad official said:

> If the development and expansion of the nation is to go on, if the progress made during the last ten years may be accepted as in any respect a measure of progress to be made during the coming decade, almost as much money will have to be expended in increasing the facilities of existing railroads, and in building additional railroads, as has been expended during the eighty years since the beginning of the construction of railroads in the United States.

These opinions are confirmed by still another prominent capitalist, who some time ago startled the investing world by his estimate of a billion dollar annual expenditure for American railroads, now actually shown by detailed estimates.

But it is especially to be noted that the keynote of the prophecies of the future is more specifically sounded in the word *capacity*, not only such as is possible and individual to electric application, but also such as is common to the larger developments of railroads, however operated.

How much has been actually spent in steam railroad development it is impossible to say, but that it is a stupendous amount, giving some suggestion of future capital demands, is evidenced by the fact that the total of the outstanding stock, bonds, and other obligations of the steam railroads in the United States now aggregate about $13,800,000,000; while similar obligations of the electric rail-

[a] Abridgment of a paper presented at the 219th meeting of the American Institute of Electrical Engineers, New York, May 21, 1907. Reprinted, by permission of author and publisher, from the Proceedings of the American Institute of Electrical Engineers, July, 1907.

roads, which began their commercial expansion with the signing of the Richmond contract almost twenty years ago to-day, exceed $3,500,000,000.

My attitude on the broad question of trunk-line operation may be briefly summarized in the simple statement that, taken as a whole, the electrical equipment and operation of trunk lines is essentially more of a financial than a technical problem. It is certainly not solvable by ingenious methods of bookkeeping, or transmission of burdens to posterity.

Fifteen years ago, in my inaugural address as president of this Institute, on the subject of "Coming Developments of Electric Railways," I said:

> Any predictions which are made concerning the future of electric propulsion, either in ignorance or disregard of the possibilities of steam duty, and the limitations necessarily existing in all systems of transportation, deserve and will receive little consideration from those charged with the responsibilities of conducting our great railway system, for unless passengers and goods can be moved over a system with increased benefit to a community, or at a reduced cost, or with a commensurate return on capital invested, an electric will not replace a steam system.

In discussing the subject of electrification of trunk lines, there is a tendency sometimes to ignore the varying conditions on the roads, and also the changes in methods of operation which the introduction of electricity may make possible. The railroads seem to be often regarded as systems which must be conducted very much on present lines; that is, operated with locomotive-drawn trains. In order to come to any clear decision, on many roads at least, this conception must be changed. There is no hard and fast rule of classification. A trunk line may generally be considered as a system joining important terminal cities, over which is conducted all kinds of traffic, through and local, passenger, express and freight, and in the larger systems a heavy suburban passenger service. The divisions and character of service of course vary widely, but the constant tendency is toward an increasing density of traffic, multiplication of tracks, and extension of the limits of local and suburban services.

A change of motive power involving vast expenditures of money and radical changes in methods of operation can not safely be determined upon except after presentation of a comprehensive report, and a general plan of equipment and operation based upon an investigation of previous practice, present or pending developments, and an analysis of important features and details. And this seems all the more essential, for at the present time the technical press is filled with the rival claims of the advocates of direct and alternating current systems, the merits and defects of single-phase, polyphase, and direct-current motors, and the beauties and ugliness, the danger and safety

EARLY SPRAGUE, DUNCAN, AND HUTCHINSON—1,000-HORSEPOWER ELECTRIC LOCOMOTIVE.

NEW YORK CENTRAL 2,200-HORSEPOWER DIRECT-CURRENT ELECTRIC LOCOMOTIVE.

of various types of overhead and third-rail constructions. High and low potentials, 15 and 25 cycle frequencies, gearless and geared motors, and air and electric controls—all are actively discussed.

But above the discordant notes there arises now and then the cry of standardization. For example, in a recent paper the view was expressed that but a single plan—the high-tension overhead trolley, with 15-cycle single-phase alternating-current motors—was possible of serious consideration on trunk-line service, and that this system should now be adopted and standardized, despite the fact that there was not in existence a single equipment of this character in practical railway operation!

I do not intend to burden this paper with statistics—one can prove almost anything by them—but I will epitomize certain conclusions which I think will bear the test of time.

1. Of the two broad lines on which electrification can be considered, if increased economy, that is, reduction of operative expenses by replacing the steam locomotive with an electric one, with concentration of prime power and perhaps the use of water power, be deemed the dominant reason for change of motive power, then every wheel in an electrified division should be turned electrically; and the savings effected should pay not only a fair rate of depreciation of the total equipment, but a satisfactory rate of interest on the new capital expended, in fact a better rate than if spent in some other way.

2. Increase of capacity, both in locomotive haulage, schedule speeds, motor-car trains and terminal facilities, of a character impossible to steam service—all resulting in augmented traffic, and increased use and capacity of the dead part of the systems, the tracks and roadbed—will ordinarily be the more potent influence in leading to the adoption of electric operation, and will often warrant heavy capital expenditures.

3. Every large road is a problem which must be considered financially and technically on its own merits, and in most features other than those which without effort can be harmonized its decision will be of little practical concern to other roads.

4. The adoption of electricity will ordinarily begin with those divisions where traffic is comparatively dense, and once adopted the territory over which it can be extended will naturally increase.

5. Terminal properties in great cities, underground and tunnel sections, and heavy mountain sections where duplication of tracks because of extra heavy construction cost is prohibitive offer an immediate field for the serious consideration of electrification.

6. There can not now be safely established any final standard, or any single system selected as the best for all roads. What is the best for one might easily be less advantageous for another, and there is no valid reason why any road should adopt something fitting to a less

degree its particular requirements because of the action of some foreign road.

7. Extraordinary advances have been and are being made, and new discoveries are always possible. The limits of none of the systems now in use are clearly defined, and it would seem both natural and wise that the various manufacturing, technical, and inventive activities should pursue every lead to its logical conclusion, for the best will be none too good.

It is not my present intention to investigate railroad economics, nor to formulate any final conclusions in the matter of steam railway electrification, but rather briefly to analyze and make running comment upon various phases of the problem often discussed by engineers; to give some comparative facts as they have thus far developed; to describe sundry developments in electric locomotive construction; and to illustrate in some detail features specifically characteristic of the three typical initial equipments now commanding attention.

Motor equipments.—In discussing the selection of any system, the first thing to investigate is the motor. In railway operation that which is to be replaced is a steam locomotive, in other words, a motor supplied by a local boiler, furnace, and coal bin; that which is proposed in its place is another motor, or group of motors supplied through a wire by bigger boilers, furnaces, and coal bins, or by energy from a water power. The working conductor, with everything connected to it in transmission or generation, although essential, is tributary to the motor and its requirements.

It is not sufficient that the source of power can be made of any desired size, although it is an essential feature; in any case such concentrated generating equipment must supply a number of motors. What *is* essential, and in the last analysis vital, is that the new motor shall have not only certain mechanical advantages, to the extent of eliminating the evils of reciprocating parts, and reducing the cost of up-keep, but above all it must have capacity, measured not alone by drawbar pull or speed, but by both, and it must be of sustained character; and to accomplish more than the steam locomotive, it must be greater than that of the latter. Such capacity should naturally be attained, first, by betterment of the individual motor or locomotive, and then, when this increase has reached its limit, by combining motors or locomotives under a common control by the multiple-unit system. * * *

Capacity being, therefore, the keynote of the equipment, I shall discuss at some length the characteristics of conductors and motors used with direct current and with alternating current. In so far as these comments relate to single-phase alternating-current operation, they will in some measure be based upon the only existing commercial development of this character now in the United States, that is,

GANZ 1,500-HORSEPOWER POLYPHASE ELECTRIC LOCOMOTIVE.

NEW HAVEN 1,000-HORSEPOWER ALTERNATING-CURRENT ELECTRIC LOCOMOTIVE.

upon the series-wound, commutating, single-phase motor with compensated fields, operated at 25 cycles.

Lowering the number of cycles to increase the capacity of the single-phase motor, as has been suggested, although not yet developed in commercial practice, of course merits serious consideration, and I shall add some comments upon this proposed change. * * *

Types of motor.—Among the many types of motors proposed for railway service, four are now being exploited: Polyphase alternating-current motor; single-phase alternating-current motor, repulsion type; single-phase alternating-current motor, series type; direct-current motor.

Of these, two, the direct-current and the three-phase motors, each have a continuous rate of energy-input, while the single-phase motor has an intermittent and variable rate. Moreover, there is combined in the single-phase motor two distinct functions, those of a motor and a transformer, and the latter can not be entirely eliminated. The result is a reduction in both continuous and overload capacities. * * *

When considering locomotives, the net result is that the total weight of a single-phase alternating-current locomotive, with a service capacity equal to that of a direct-current locomotive of like armature speeds and permissible temperature-rise (this temperature-rise being the ultimate limitation of a motor for continuous service), will easily be from 30 to 50 tons more.

An increase in the total weight of a train amounting to from 3 to 10 per cent is perhaps not of itself of so much importance, because such a difference in net power demand can easily appear for various reasons; but a ratio of 2 to 1 in capacity for the limit of equipment possible to install within given allowable dimensions and number of units is a matter of vital importance.

Comparative weights of direct-current and 25-cycle single-phase alternating-current motors.—While the testimony is practically universal that not only is any single-phase motor, whatever the number of alternations, more or less inefficient than a direct-current motor of like weight or capacity, the differences of efficiency, excluding the losses in the gearing, are variously estimated. * * *

An increase of 10 per cent in the amount of current used on a direct-current system, because of improper gear-ratio, change of schedule, or careless handling of equipments by motormen, does not mean that this excess energy is dissipated in internal losses in the motors, for these may be increased only about 1 per cent. The situation in regard to the single-phase motor is, however, entirely different for it is subject not only to increased power consumption with its proportionate losses because of careless operation, but it also has its individual increased internal loss, which is variously estimated to be

much more than that found in properly designed direct-current motors of equal weight and like physical limitations. * * *

It is customary to adopt a single-phase alternating-current motor rating which is based upon the performance of some direct-current motor. For example, a 125-horsepower single-phase machine is supposed to do the same work, that is, handle the total number of tons on some specified service, as a 125-horsepower direct-current motor. This may be an ingenious comparison, but it is misleading. The fact is that such a motor equipment, including its transformer, will be much heavier than the motor equipment with which it is compared, and consequently the net load which it can handle will be much less.

What *is* of vital consequence is a *comparison of capacities for equal weights*, not only of motors but of total apparatus which must be carried on a car, and also to compare the speed-relations and the polar-clearances, in other words, the allowable wear of bearings, all of which is quite aside from gear and commutator brush considerations, which are of themselves serious.

Valatin and others have indicated one measure of comparison between motors of different makes, types, and capacities—the "weight-coefficient,"—which for convenience may be expressed by the following equation:

$$\text{Weight-coefficient} = \frac{\text{Nominal rated horsepower.}}{\text{Revolutions} \times \text{weight in tons.}}$$

This is a factor of the greatest importance, and it should be considered not only for the one-hour 75°-rise load, but throughout the whole thermal curve.

Let us investigate two standard modern machines.

An initial comparison is as per this table:

Machine.	Type.	Voltage.	Air gap.	1-hour rating, horsepower.	Weight, pounds.
X	Direct current	550	0.25	240	5,473
Y	25-alternating current	225	.10	125	5,274

The weights are minus pinions, gear, and gear cases. There is a difference of less than 4 per cent in net weights, or about 2.5 per cent in total weights. * * *

The accompanying curves (fig. 1) show graphically, almost startlingly, the comparative speeds, capacities, and weight coefficients of these machines, all referred to the time required to rise 75° in temperature when operating at full normal potential under varying loads and with natural ventilation.

Generally speaking, it will be noted that, starting at 500 revolutions for a 39-minute run, the capacity of the direct-current motor averages approximately nearly double that of the alternating current throughout the thermal range; the speed of the alternating-

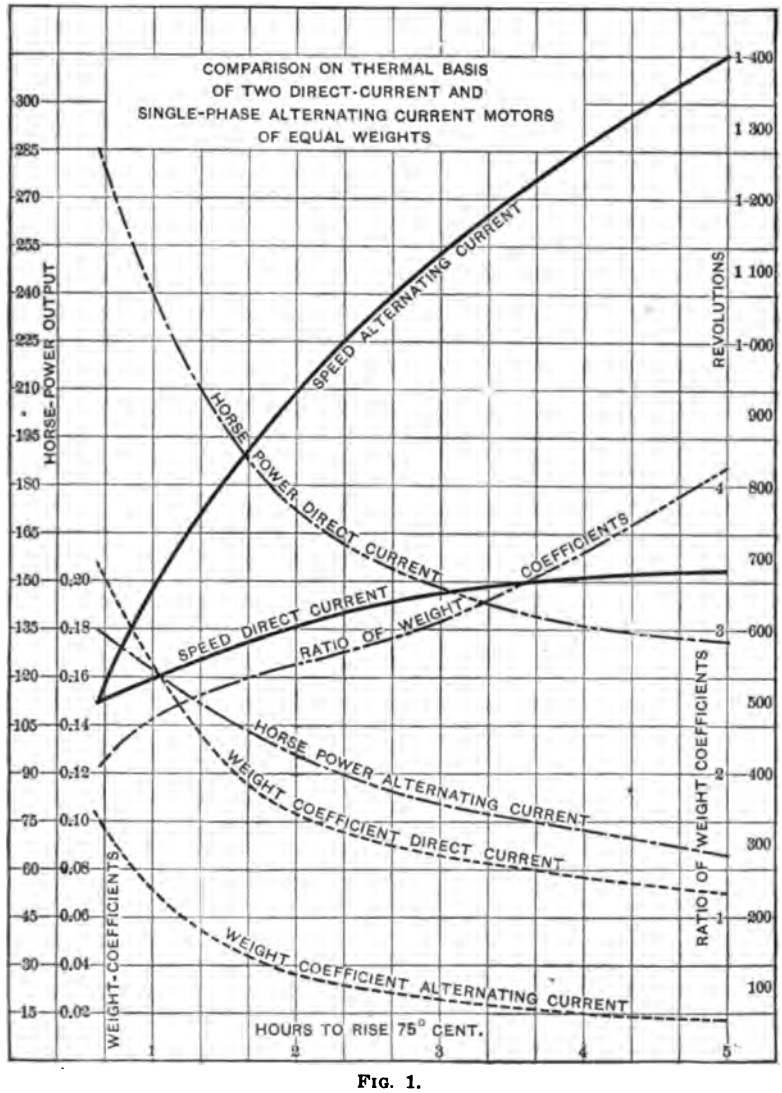


FIG. 1.

current motor rises at a much more rapid rate, until on a 5-hour run it is double that of the direct-current motor, despite the fact that it is only developing one-half the power; the direct-current motor has a 5-hour capacity in excess of the 1-hour capacity of the alternating-current motor; and the ratio of the weight coefficients, begin-

ning at a trifle of over 2 to 1, rises to more than 4 to 1 in favor of the direct-current motor on the longer runs. This comparison of weight coefficients does not include the collectors, control switches, rheostats, transformers, or wiring, which in the aggregate are enough heavier for the alternating-current motor to maintain these disparities.

It is evident, therefore, that a pair of these alternating-current motors can handle only about one-half of the total load of the direct-current motors, with all the disadvantage of higher armature speed and smaller air gaps; and considering the excess weight of the control apparatus, the net load over and above the electric equipment would be considerably less than one-half.

This general comparison is not, so far as the relative characteristics are concerned, individual to this particular size of motor, but seems at present to be equally applicable through a wide range, and indifferently as to the make, or whether the alternating-current motor is of the series-compensated or the repulsion type.

Polyphase and direct-current motor characteristics.—Opposed to the two types of single-phase motors are the polyphase and the direct-current motors, the former with a rotating field and the latter with a field of fixed character. They have similarly high weight efficiencies, the former having somewhat the advantage when compared with the ordinary type of direct-current motor.

The polyphase motor, however, is a normally constant-speed machine. It can, through a rearrangement of fields, be run at two different speeds, but each is practically a constant one. Or where there is a plurality of motors, half and full speed can be obtained by having one pair of different character from the other, and operated in cascade relation to it, with the necessity, however, of throwing one pair of motors out of service when running at full speed. With cascade operation and field changing combined there can be three running speeds. These motors, so far as their supply is concerned, have been limited for practical reasons to a potential of 3,000 volts on the trolley, because the supply requires, besides the rail, two wires overhead, although a recent undertaking in the United States, the operation in the Cascade Tunnel, is to be attempted at 6,000 volts.

Polyphase motors have an enormous overload capacity, and the fact that they run at synchronous speeds with a very small slip, and if the frequency is unchanged will run upgrade nearly as fast as on a level, would indicate at first sight excessive loads on main and substations. But a curious and perfectly natural result has been pointed out by Cserhati and Von Kando, namely, that with suitable provision for regulation at the central station, so that with excessive loads the generators will drop in speed, there will, with such speed reduction, be

not only a temporary cessation of drawing power by the locomotive, but there may actually be a return of energy to the line while slowing down. While of course this slowing down affects all trains on a system, it is quite conceivable that when there are a number of trains in operation a mean result may easily be attained which will, in the matter of load fluctuation, compare favorably with that of any other system. Multiple-unit grouping and operation is ordinarily impracticable because of the small slip. In spite of the splendid work done by the Ganz Company, and the strong support of many Italian engineers, I feel that, all things considered, neither the motor characteristics nor the limitations of overhead construction are acceptable for such service and conditions as exist on our trunk-line roads.

On the other hand, considered by itself, the direct-current motor, with its high average weight efficiency, simplicity of construction, facility of control, automatic response in torque and speed to varying grades and curvatures, and great sustained capacity for enormous torque at low speed, besides the advantages of speed-ranges obtained by motor-grouping, and the use of a single conductor and track return, offers a most effective machine to meet the conditions of much of our railway service. Through it, as with the polyphase machine, the "ruling grade," often of limited length, is eliminated, for the motor can always respond to these temporary demands up to the limit of track adhesion.

Direct-current motor improvements.—During the last two years important developments have taken place in direct-current motor construction which materially change any preconceived conclusions as to its limitations.

The first is the introduction of the commutating pole, which has practically eliminated commutator troubles, such as sparking, undue heating, and flashing over, so that even a four-pole machine, within a wide range of potential and load, runs absolutely black at the brushes. That this improvement has reached a high degree of commercial standing, despite very recent technical criticism and opposition, is evidenced by the fact that orders for nearly a thousand such railway motors have been placed within the last two months.

This improvement makes possible the shunted-field addition to the series-parallel control of speed, the construction of motors for operation at much higher potentials, and the operation of two motors in series at double potential.

An especially important development is that illustrated by the gearless locomotives built for the New York Central Railroad (pl. 1), in which the hitherto invariable practice of maintaining a fixity of relation between the armature, or rotating part, and the field magnet, or fixed part, has been abandoned; the armatures are

mounted directly on the axle, the field magnets forming a part of the locomotive frame, supported by its springs and hence movable with regard to the armatures. In this constructoin, therefore, there are no armature or field bearings. This locomotive is of the simplest type possible, electrically and mechanically, and when operating under conditions for which it is properly applicable it has not only the highest weight efficiency, but the lowest cost of repairs of any direct-current machine, and much lower than is possible for any single-phase locomotive. It is structurally a natural high-potential machine on account of having but two poles.

Difference between direct-current and single-phase alternating-current motors.—The present inherent differences between direct-current and single-phase motors may be briefly summed up as follows:

1. The input of current in one is continuous; in the other intermittent.

2. One has a single frame, the electrical and mechanical parts being integral; the other has a laminated frame contained within an independent casing. Hence there is not equal rigidity, or equal use of metal.

3. One has exposed and hence freely ventilated field coils; the other has field coils imbedded in the field magnets.

4. One has a large polar clearance, and consequently ample bearing wear; the other has an armature clearance of about only one-third as much, and hence limited bearing wear.

5. One is operated with a high magnetic flux, and consequently high torque for given armature-conductor current; the other has a weak field, and consequent lower armature torque.

6. One has a moderate sized armature and commutator, and runs at a moderate speed; the other, with equal capacity, has a much larger diameter of armature and commutator, and runs at a much higher speed.

7. One permits of a low gear reduction, and consequently a large gear pitch; the other requires a higher gear reduction and a weaker gear pitch.

8. The windings of one are subject to electrical strains of one character; in those of the other the strains are of rapidly variable and alternating character.

9. The mean torque of one is the corresponding maximum; the mean torque of the other is only about two-thirds of the maximum.

10. The torque of one is of continuous character; that of the other is variable and pulsating, and changes from nothing to the maximum fifty times a second.

11. One has two or four main poles only, two paths only in the armature, and two fixed sets of brushes; the other has four to twelve

poles, as many paths in the armature, leading to unbalancing, and as many movable sets of commutator brushes.

12. One can maintain a high torque for a considerable time while standing still; the other is apt to burn out the coils which are short circuited under the brushes.

13. In one, all armature-coil connections are made directly to the commutator; in the other, on the larger sizes, resistances are introduced between the coils and every bar of the commutator, some of which are always in circuit, and the remainder always present.

14. In one the sustained capacity for a given weight is within the reasonable requirements of construction; in the other it is only about half as much.

15. Finally, the gearless type, with armature and field varying relatively to each other, is available for one, but this construction is denied to the other.

Consideration, then, of the characteristics peculiar to each class of motor indicate, not that the single-phase motor can not be used, but that if adopted the weight or number, and the cost of locomotives or motors required to do the work must be much greater; that the depreciation of that which is in motion will be higher; and that there will always be an excess weight of fixed amount per unit which must be carried irrespective of the trailing or effective loads. We must, therefore, in many cases be led to the selection of the direct-current motor, that motor which has the higher weight capacity, the greater endurance, and the lower cost per unit of power.

Electric braking.—Recuperation of energy to reduce the amount of power used, and to make the motors act as brakes to retard the acceleration of a train, has been a favorite project, and attended by many prophecies since the beginning of the electric railway industry. * * *

On ordinary railroads the gradients are not sufficient to make it worth while to attempt any recuperation of energy; the acceleration due to any excess of gravity coefficient above that necessary to overcome the friction of the train is usually welcomed. On mountain roads, however, electric braking may become an important adjunct, not because of power economy, but for safer operation. In any case, simplicity of application and absolute reliability of action are first essentials.

There are two general methods available: One in which the energy of the descending train drives the motors, acting with shunt or independent field characteristics, at an aggregate potential above that of the line at the rail, and sending current back into the line; another in which the motors are disconnected from the line, and driven as self-exciting generators on a closed circuit, as much of the energy of the descending train as desired being used up in heating rheostats. * * *

Comparison of direct-current and alternating-current braking.—On the general subject of braking it should be pointed out that with direct or continuous current motors there is always a residual magnetism in the fields because of their construction, and the fact that the exciting current never changes direction. Such machines, therefore, can always promptly build up automatically when properly closed upon themselves, and the reverser is set in the proper direction.

A similarly effective method of braking has been claimed for motors operated by single-phase alternating currents, but it would seem that in this case there is not the same degree of reliability. In such motors the field is laminated to the last degree to cut down heat losses, and to increase the capacity; it will hold but little residual magnetism under any circumstances, and furthermore the field is excited by a rapidly varying alternating current. It is therefore possible that at times the field will be nearly inert, and comparatively slow, with its low-turn winding, in building up, or possibly the field may be entirely inert, and may refuse to build up at all. There seems, therefore, no certainty whatever that a single-phase alternating-current motor, disconnected from the line, and without any other exciting source, will, when closed upon itself, always build up into a braking dynamo.

All things considered, reliability and simplicity of operation dictate the use of the self-exciting method of braking with the direct-current motor, which lends itself to that purpose in the highest degree.

Working conductors.—Whatever motors are used—and all the principal types will be used—there are various methods of construction and use, especially as applied to locomotive building, and alternate methods of current supply and use.

Generally speaking, conductors may be divided into two classes: Flexible or rigid overhead, and third-rail. One would suppose from many references and some of the arguments which have been made, that direct-current systems are essentially and necessarily dependent upon the third-rail, and that the overhead trolley is a thing individual to, and has been developed for, alternating-current operation only. This impression should be corrected, not of course for the information of engineers, but because this somewhat erroneous idea is in danger of being accepted as a fact by non-technical men.

The overhead system has been a distinctive feature of all electric roads operated by direct current since the days of the historic Richmond road, with the exception of those using the third rail; and until recently the only practical modification has been the somewhat limited use abroad of the sliding bow or roller in place of the grooved trolley wheel. This latter, although used with high speeds on inter-

urban roads, is unfitted for trunk-line operation, and where overhead trolley wires are used the long collector will probably take its place.

Physically, the overhead trolley is not individual to any particular system; practically, its use depends upon the amount of current which has to be collected. If at low potentials, then it must be either strongly reinforced, and there must be a plurality of contacts, or if these are diminished the amount of current to be collected must likewise be reduced, and the potential raised. In the abstract, therefore, the possible use of the overhead trolley, no matter by what system, is a question of allowable operative potential, and the amount of current which can be practically collected.

Until recently the invariable practice with overhead construction has been to use a flexible wire supported at comparatively long distances on tangents, with pull-off at curves, and easily yielding to the pressure of a trailing trolley. This is the practice which characterizes not only direct-current trolley operation, but has also distinguished practically all operation abroad where single-phase or polyphase currents have been used. The introduction of high tensions has, however, now made it necessary to provide by additional supports against the possible breakage of the trolley wire. This has led to the introduction of catenary construction, the catenary being either single and supporting the trolley at frequent intervals, or double to prevent lateral swaying. In the former case the trolley is only partly flexible, and in some cases the support has been supplemented by an intermediate catenary, as on the Blankenese-Ohlsdorf Railway, where greater flexibility of the trolley wire itself is insured by loosely suspending it from the lower member of the catenary instead of making the latter the trolley wire, and providing for varying the tension. In other cases it is to some extent maintained by having less frequent supports, and also by introducing a movable part at the suspender.

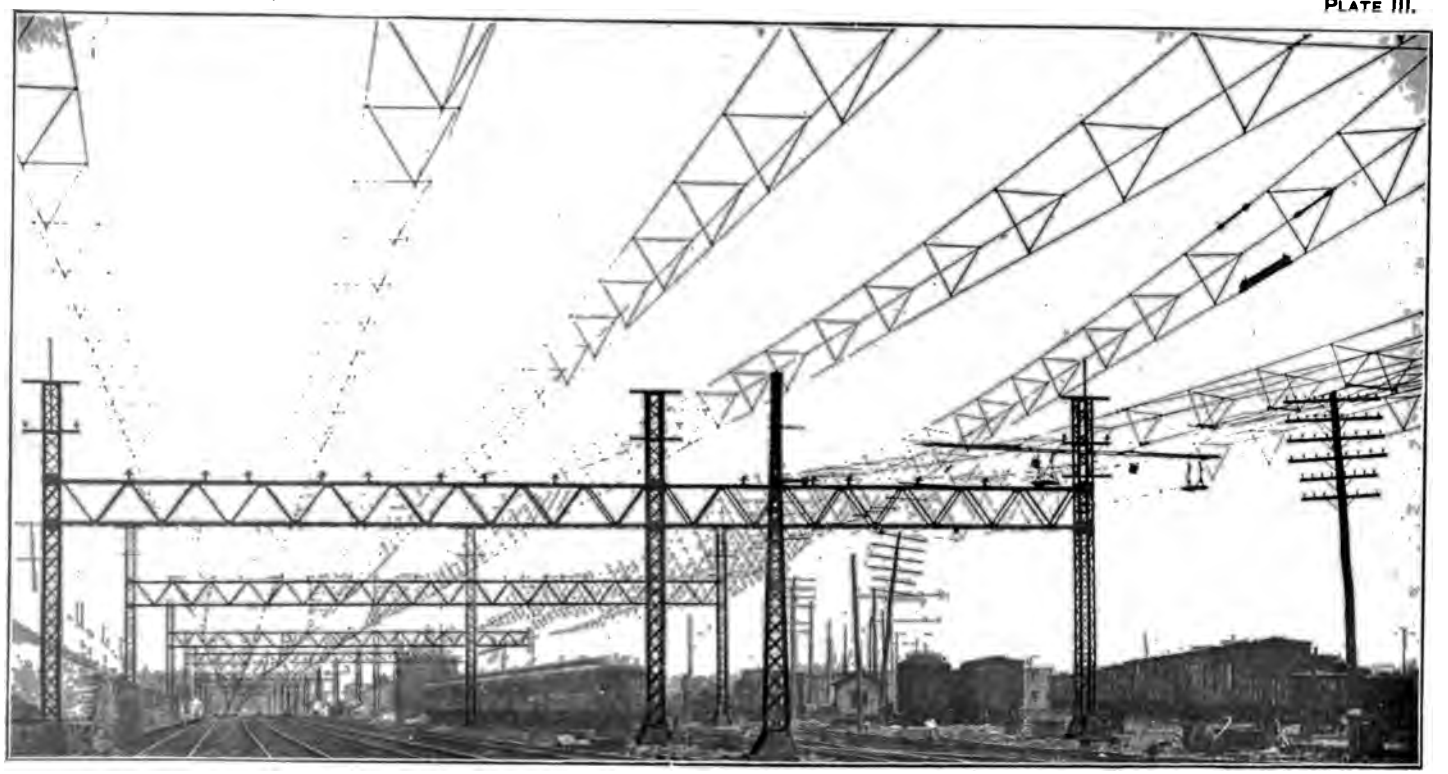
The most recent and extended application of double-catenary construction is that on the New Haven road for use with its single-phase locomotives (pl. III). Here a trolley wire is put under high tension and is supported at frequent intervals by solid clips attached to rigid triangles, in turn secured to galvanized-iron wire cables carried on insulators on the top of bridges which span the tracks at intervals on tangents of about 300 feet. The catenaries are drawn together between the spans so as to give the utmost rigidity to the whole system, the intent being to maintain the trolley wire as nearly as possible in one plane. At cross-overs and sidings the supporting triangles overlap, and the angle between the junction and the trolley wires is filled with additional conductors, more readily to insure safe passage of the vertically moving sliding contact which has been adopted. At intervals of about 2 miles the trolleys are sectionalized at anchor

bridges, where are provided the necessary switches for cutting out sections, and for looping to extra supply conductors.

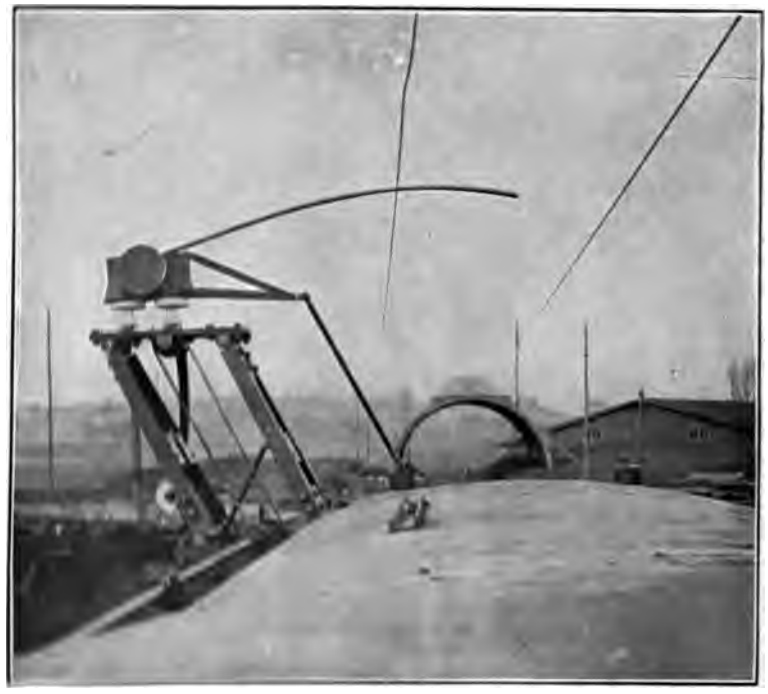
The modern pantograph consists of a sliding or rolling contact, which forms the upper number of a light yet strong collapsible structure maintaining an upward spring pressure. The theory of this system of collection is that a locomotive normally moves between two parallel planes, on one of which it runs and from the other of which it collects current, and that the ordinary motion of the contact will be inappreciable. This assumption is, however, modified in practice. The collectors are carried normally 22 feet above the track on a superstructure (pl. II) which must respond in some measure to track irregularities, and which has considerable inertia and some friction. There is a drag because of friction against the trolley wires and wind pressure due to motion of the locomotive. This upward pressure must necessarily be changeable because of variation of angle, friction, and the resultant motion. To maintain contact it must rise and fall. When traveling 70 miles an hour it passes supports which are more or less rigid nine times a second, and between these supports the trolley wire, no matter what the tension, will be convexed upwards. As the collector approaches any suspender the pressure will normally considerably increase, and, as it leaves it, diminish. The practical question arises whether, considering all the forces acting on it and its inertia, it can satisfactorily respond in addition to other requirements to a double change in vertical direction nine times a second. If contact depended upon the whole structure of the pantograph moving thus rapidly some trouble might be anticipated, but possibly the elasticity of the upper part will prove sufficient.

An ingenious method of making contact with an overhead single trolley line is that developed by the Oerlikon Company under the direction of Mr. Huber (pl. IV). In this system the trolley is stretched with comparative rigidity on top of insulators supported on posts alongside the track, with cross-overs where needed. In place of the ordinary wheel and bow trolleys, a curved hinged arm of fair length, and sweeping over nearly one half a circle in a plane transverse to the line of track, is supported on insulators on the side of the car. Normally, this bow rests on top of the wire, pressing lightly on it, and thus avoiding the under formation of icicles. On cross-overs and in tunnels, where the trolley wire is carried over the track, the arm swings toward the center of the car, and is depressed, making contact progressively from the top around to the side, and then underneath the trolley wire. In addition, the saddle which carries the bow is movable laterally, increasing the radius of action. Of course two bows can be used.

The alternative type of working conductor is the third rail, already adopted on about forty roads, some of considerable extent, most of



DOUBLE OVERHEAD CATENARY TROLLEY ON NEW HAVEN ROAD. FOUR TRACKS AND SIDING.



OERLIKON TROLLEY—UNDER-CONTACT.

PROTECTED THIRD RAIL ON FOUR-TRACK DIVISION, NEW YORK CENTRAL.

them with heavy passenger traffic, and operated under greatly varying conditions. A large proportion of these roads have used the ordinary type of top-contact rail, carried by insulators on the ties, sometimes entirely exposed, and again partly guarded by side boards, as on the Manhattan Elevated, or by a wooden shield carried by yokes from the rail itself, as on the Interborough. While this is the simplest form of third-rail construction, and has given good service for years, it has certain disadvantages. If exposed, it is a constant

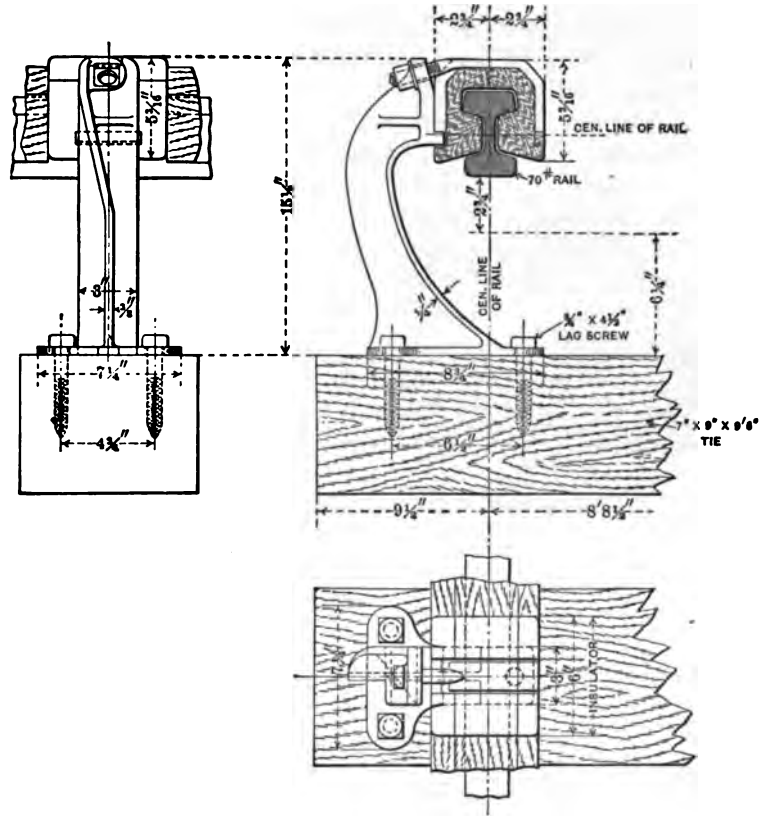


FIG. 2.—Details of Wilgus and Sprague protected third rail.

menace, especially in yards; and even when guarded it can not be wholly protected from snow and ice. The lower part is only about 4 inches above the tie, while the holding clips generally used reduce even this clearance, so that the danger of grounding from accumulation of wet snow and ashes, and from flooding is increased. In the latter case over-all flooding has the whole rail surface for leakage.

These various objections led to the abandonment of the top-contact rail in connection with the New York Central work, and the development of an under-contact sheathed rail supported by insulators from

brackets carried on the ties, and with the body of the rail about 9 inches clear (fig. 2). This type of rail has been adopted for the 285 miles of trackage under electrification, as well as on a number of other roads.

The structure consists, briefly, of a series of iron brackets carried on the ties, to the tongued vertical face of which are clamped non-charring moisture-proof insulator blocks which loosely embrace the head of the rail. Intermediate between the insulators the rail carries an insulating sheathing, which embraces the head and reaches down nearly to the bottom face of the rail, but extends outward from the web to form a petticoat protection against snow and sleet.

For moderate potentials, say of 600 volts, the two halves of the insulator blocks are alike, but for the higher potentials the inner insulator block, that is, the one next to the face of the bracket, is extended so as partly to shroud the head of the bracket. The sheathing between the insulator blocks, depending upon local conditions and price of materials, as well as potential used, is formed of three wooden strips, one grooved on the under side and inclosing the head of the rail, and the other two, attached to and dependent from it, reaching in towards the web of the rail. Where good wood is not available, an alternate protection, costing about the same and having a higher electrical resistance, although not quite so good a mechanical one, is a semiflexible shell of indurated fiber conformed to the rail-section. * * *

General comparison of working conductors.—All working conductors are in many ways objectionable, but since they are a necessary connecting link between the source of supply and the motors, some comparisons may be made of the two kinds, the under-contact, protected type of third rail and the overhead trolley, as affected by construction and operation.

The third rail is an inert structure; it can be aligned accurately with the track, is not under strain, and its expansion can be readily taken care of. The overhead trolley is necessarily a system under strain, and where permanency is desired and high potentials are used it must be carried by one or more catenary cables, which on roads of high curvature makes the construction more difficult. Its alignment in the latter case does not correspond with the line of track, and as ordinarily constructed it is subject to extreme variations of tension on account of weather changes.

The third rail offers some hindrance to the ordinary maintenance of track; but overhead construction is inelastic, and the laying of additional tracks or changes in grades or alignment require radical and expensive alterations or additions in permanent overhead structures.

Derailments will crush one form of conductor to the ground, forming a short circuit which will cut off the section; but they may also knock down the supporting structures of the other, and, where there is a plurality of tracks, put them all out of service.

In wrecking, the third rail offers some obstruction to the throwing of the equipment to one side; but, on the other hand, overhead conductors may interfere with the operation of the crane booms of the wrecking car.

Where there are two or more tracks snow can not be piled up between them if the third rails are located there; but, on the other hand, overhead conductors are a source of danger to train men, to snowshed and tunnel repairers, and in the open are subject to troubles of sleet formation.

The third rail will oftentimes be covered with snow, but is unaffected by sleet. Very thorough tests made in connection with the New York Central work show satisfactory operation, not only in sleet storms, but with the rail buried in snow. Additional depth should not add much difficulty. With regard to frogs and switches, there are no problems which can not be solved with this type of third rail, with an occasional overhead section, and any required amount of power can be collected at operative speeds.

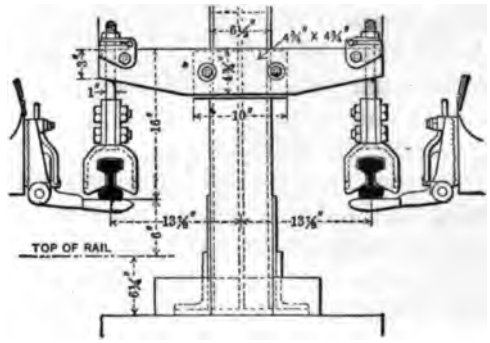


FIG. 3.—Details of Wilgus and Sprague protected third rail on Philadelphia Rapid Transit Railway.

On western roads, where a rotary snowplow is used, overhead conductors and the supporting insulators, especially in yards, will be subject to a heavy bombardment of snow, ice, and refuse, with possible resultant breakage, and the under sides of the umbrellas of the insulators will be often filled up with wet snow.

Then there are corrosion and soot deposits when steam and electric operation are maintained over the same track. Where the steel supporting bridges also carry signals, as is proposed in some cases, there is increased danger to men engaged in cleaning, painting, or repairing overhead structures and taking care of signals; and when spanning two or more tracks there is a possible interception of the train operator's view of signals because of dips in the railroad grades bringing overhead bridges in front of the semaphores, which like-

wise may be made less distinctive if they have truss members for a background.

Relative direct-current potentials in overhead trolley and third rail.—Now that the improvements in direct-current motor construction, not only those promised but those actually accomplished, have made it possible, quite irrespective of what may be done with alternating-current motors, to use much higher potentials than ordinary—not, of course, as high as those available in single-phase alternating-current systems—the question sometimes arises, Will not the permissible potential be high enough, taking into account certain other facts, to meet in large measure the demands of railroad operation, whether by overhead or third rail?

Engineers have generally proceeded on the assumption that the use of a sufficiently high potential for practical purposes is possible only with overhead conductors. In the Siemens-Schuckert installation at Mazières, where 2,000 volts direct current are used, the current is taken from two trolley wires of like potential supported by cross-wire catenaries from side poles of the same construction as is commonly used to carry the warning tickler.

Again, the third-wire system has been proposed, as on the Krizik road, and, on a recent installation with many grades and heavy tunnels in the Iselle mining district in France, where two overhead trolley wires are used at 2,400 volts, with the track as a neutral, and with the motors grouped in series of two, current being supplied by two Thury generators in series and grounded in the middle.

A comparison of potential relations giving the same losses on three systems is interesting. The systems are:

1. Three-wire, with two No. 0000 trolleys and 75-pound bonded single track.
2. Two-wire, with same trolley wires and track return.
3. Third rail, 70-pound special, and with same track return.

The following table gives the comparisons:

System.	Resistance per double mile.	Ratio of resistance.	$\sqrt{\text{Ratio.}}$	Comparative voltages.	
	Ohms.				
No. 1	0.52	6.6667	2.58	2,400	3,100
No. 2	.165	2.1154	1.45	1,350	1,740
No. 3	.078	1.0000	1.00	930	1,200

On such a showing there is little excuse for departing from the lower potentials and the simpler systems, and being handicapped with the higher voltage problems and complication of switches in the three-wire system. If any smaller trolley wire be used, then the disparity between Nos. 1 or 2 and No. 3 would be emphasized.

PROTECTED THIRD RAIL AFTER SLEET STORM.

PROTECTED THIRD RAIL BURIED IN SNOW.

The relation of potentials indicated in this table raises the question whether, in view of the disparity of current conducting capacity between an overhead system and the third rail, it is not also possible that a sufficiently high potential can be used on the latter if from a practical railroad standpoint the balance of advantages and objections should be enough in its favor to warrant its material extension.

Some time ago I stated that in my opinion it was practicable to operate at double the ordinary potentials with a properly protected under-contact sheathed third rail. I am glad to be now able definitely to announce that it seems possible to construct and operate at these increased potentials with a degree of safety hitherto deemed doubtful.

Fifteen-cycle operation.—The principal object sought, and certainly a most desirable one in the use of higher potentials, whether direct current or alternating current, is not now so much reduced cost of working conductors on a trunk-line system—for practice has shown that this cost is not materially affected—but lessened feeder investment, increase of substation distances, reduction of total substation capacity, and, in the single-phase system, the abolition of moving machinery in the substations. * * *

The degree of success of the alternating-current development will depend primarily on the development of capacity and all-round operative features in single-phase locomotive and car equipments. The 25-cycle motor (hitherto the only frequency actually installed for single-phase equipments), whether judged by individual comparison or specific equipments, as I have already illustrated, or the general testimony of electrical engineers of manufacturing companies, has proved inadequate when compared with its rival. To correct this defect it has been proposed to adopt 15 cycles as a standard of operation.

This number of cycles has been under consideration for some time. It is successfully used by the Ganz Company in its polyphase installations, it has been proposed in this country by the General Electric and Westinghouse companies for important work, and has lately been urged as a standard by a number of engineers.

Motor and locomotive constructions.—Motors are of the geared and gearless types, may be entirely separate units or partly integral with the truck frame, and may be wholly or partly spring-supported. Locomotive designs, influenced in part by the type of motor adopted, show a great variety of constructions, and may be very generally classed as rigid frame with all weight on the driving axles and without leading trucks, rigid frame with either single axles or bogie leading trucks, and bogie-truck locomotives, the bogies being pivoted under the cab, and sometimes linked together.

On all multiple-unit trains, except such as are designed for very high speed, in which case there is a possibility of a gearless-motor development, the standard method of motor mounting I introduced on the Manhattan Elevated Railway in 1886, and which has been in vogue ever since, bids fair to continue. It provides for sleeving the motor and carrying a part of its weight upon the driven axle, to which it is connected by any required ratio of gearing, the free end being flexibly suspended from the truck above the side springs.

Up to capacities of 250 horsepower, about the limit required and permissible for motor-car equipment, single driving on one end can be used; but when this type of motor is built for larger sizes, in connection with locomotives, it seems almost necessary to provide for gear driving at each end, which presents some difficulties in construction.

The rigid wheel-base type of locomotive without leading trucks is illustrated by a direct-current machine built under the direction of some associates and myself a number of years ago for experimental work on one of the lines running out of Chicago, and also by one class of double-unit locomotives which has been frequently proposed by various companies for single-phase alternating-current operation. * * *

An analysis of the action of a locomotive demonstrates beyond question that this general type of machine—that is, one having a rigid frame and no guiding trucks—is limited to moderate speeds, and would be unsafe if operated at high speed on a road with much curvature and special work.

Particular interest naturally centers upon the distinctive types of locomotives installed on four important railway systems, the Valtellina and the Simplon Tunnel in Switzerland, the New York Central, and the New York and New Haven, which well illustrate three of the principal methods of construction developed to meet the demands of different electrical systems. I will briefly describe each, as well as make some comment upon a few of the many other types recently proposed.

As illustrating a high order of electrical and mechanical engineering, the work of the Ganz Company merits special mention, for it is undoubtedly true that the present status of the polyphase system, which stands on a favored plane with many Italian engineers, is owing almost entirely to the efforts of this company.

The polyphase motor locomotives (pl. II) built for the Valtellina Railway and for the Simplon Tunnel are strikingly individual in their construction. The axle mounting of motors is abandoned, the motors being entirely separate units mounted on the locomotive frame, and coupled to each other and the 62-inch driving wheels through an ingenious combination of connecting and side rods. Of

the three pairs of main drivers, the middle only is journaled in the main frame, each end pair being journaled at one end of a pivoted guiding truck, at the outer end of which are guiding wheels about one-half the diameter of the driving wheels. The end drivers have a limited end play, and one king bolt has a similar freedom of movement, while the other is fixed, resulting altogether in great freedom of adjustment to track curvature. The two motors, spring-supported through the locomotive frame, are each quarter-cranked and connected to side rods having downwardly projecting jaws which loosely engage the driving pins of the middle drivers, the centers of which are somewhat below the centers of the motors. On each side of the jaws of the side rod are coupled the connecting rods of the outer drivers, provision being made in all bearings for the necessary freedom of movement and adjustment.

In an earlier type the locomotives were equipped with two sets of twin motors for high and low tension, the low tension to be operated in cascade relation to get slow speed in starting and for running on grades, then to be cut out, and the regular running to be with the high-tension motors alone. In the latest machines the twin-motor construction has been abandoned, and the locomotives are equipped with two 15-cycle high-tension polyphase motors, one having 8 and the other 12 poles, and an arrangement of field circuits in the latter machine such that it can be temporarily made a low-tension motor operating in cascade relation with the other. This combination permits of three regular operating speeds of about 16, 26, and 40 miles per hour. At the lowest speed the motors are in cascade relation, with high draw-bar pull; at middle speed the 12-pole motor is in operation alone on high tension; and at the highest speed the 8-pole motor is used alone, likewise on high tension. Of course the physical connection of the two motors together and to all drivers makes this method of operation possible. The rated capacity of the motors, as given by Valatin, is extraordinarily high, that with the 12 poles being stated as 1,200 horsepower, and that with 8 poles 1,500 horsepower, based upon the one-hour rise of temperature to 75°. The motors average about 13 tons each.

The use of connecting rods in this locomotive is not as objectionable as the use of the driving and connecting rods in a steam locomotive, because the strains are very different, and the rotative weights can be far more perfectly balanced. It can be fairly said to have the advantage that with the minimum possible weight of locomotive there is no such thing as slipping an individual wheel, a trouble which will occur at times with all locomotives having independently driven axles if equipped with powerful enough motors, because of variation in motor characteristics, track and wheel conditions, and unequal wheel pressure caused by the drawbar pull.

Almost the entire weight of the locomotive is spring borne, and the behavior of the machine on curves even at high speeds ought to be very satisfactory. The same general construction would lend itself very effectively to the application of high-tension inter-pole direct-current motors, and may be very seriously considered in this connection.

The general characteristics of the New York Central type of locomotive (pl. 1), the Batchelder machine as developed by the General Electric Company, is pretty generally understood, and my description will be limited. It consists essentially of a heavy steel frame in which are journaled four main axles, and which is terminated by pivoted

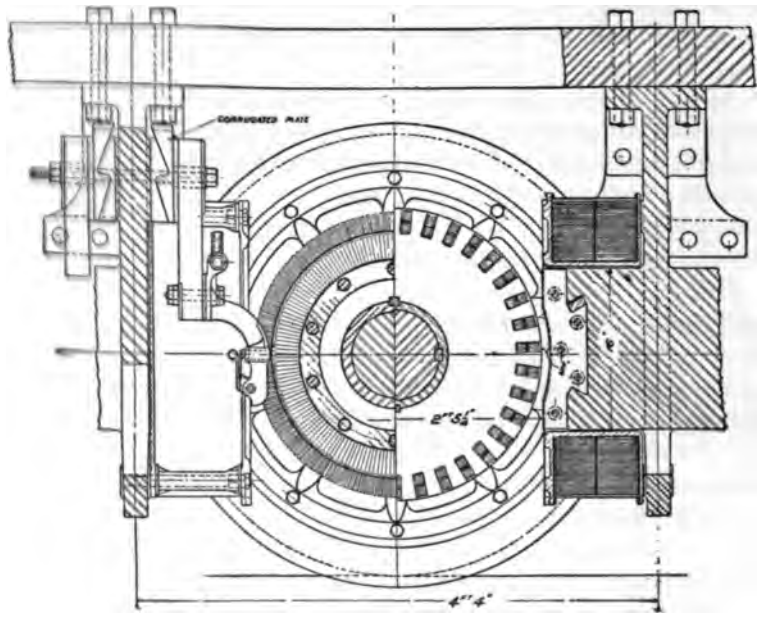
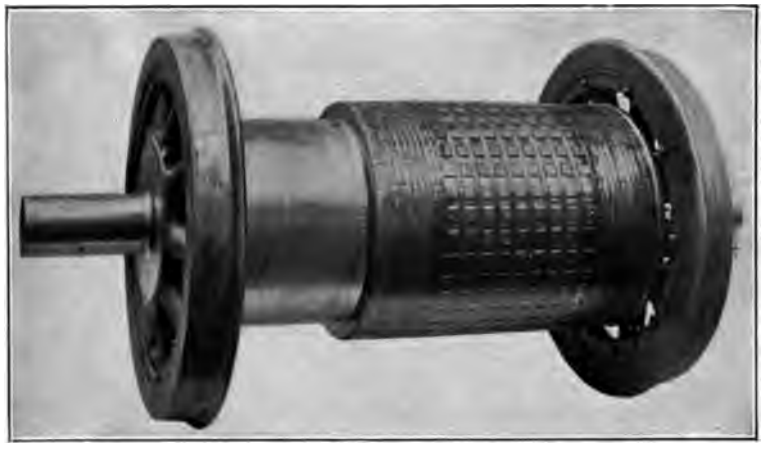


FIG. 4.—Longitudinal section—bipolar direct-current motor.

single-axle ponies provided with spring resistance against deflection from the central position. The motors are the gearless type, the armatures being mounted directly on the axles (Pl. VI) and the bipolar field magnets forming an integral part of the main frame; they are, therefore, carried with it by the equalizing springs, and have free motion relative to the armatures. In addition to the regular truck frame, an additional path is provided for the magnetic flux, which passes through all the armatures and field poles in series, by a heavy bar extending the length of the frame, and carried above the motors.

Being of the two-pole type (fig. 4) and with a quadrant winding, the motors are extraordinarily free from sparking tendencies; in fact, they are, structurally, natural 1,200-volt machines, although only wound for present operation at 650. So marked is this characteristic,

the brushes, which are 180° apart, instead of being carried on



ARMATURE OF BIPOLAR DIRECT-CURRENT MOTOR.

MOTOR AND AXLE UNIT OF ALTERNATING-CURRENT NEW HAVEN LOCOMOTIVE.

yokes concentrically with the commutator, are carried on arms attached to the field-magnet frame, and although moving with it function perfectly.

The electrical and mechanical construction is, therefore, reduced to an acme of simplicity never hitherto attained in electric locomotives, for not only are there no gears, but there are no armature or field bearings, quills, driving spiders, or special spring connections, although all the weight of the motors except the armature is spring supported.

The air gap is very large, and as the pole pieces are very nearly flat a complete axle unit with its armature can be readily dropped out and replaced without disturbing the balance of the motor equipment. This type of machine, of course, can not be used with any form of alternating-current directly, no matter what the frequency.

When first proposed the design was considered so radical that its choice met with a good deal of criticism, but experimental trials extending over two years, with 67,000 miles of operation, amply demonstrated its remarkable reliability and efficiency, qualities confirmed by the operation of thirty-five of these locomotives now delivered and in regular service.

The total weight of the locomotive, without heating equipment, is about 95 tons, of which 70 tons is on the drivers. The nominal capacity, with 75° rise and natural ventilation, is 2,200 horsepower, at which output with 600 volts the motors run at 300 revolutions, corresponding to 40 miles an hour. The rigid wheel base is 13 feet, the total wheel base 27 feet, and the length over all 37 feet.

The individual control is the series-parallel bridge method, with resistance variation, the grouping of motors varying from four in series to four in multiple, and current is taken from the under-contact rail by side-extending spring flipper shoes.

The exigencies of service are responsible for a recent remarkable test. On April 26 the Lake Shore Limited, north bound, consisting of nine heavy Pullman cars hauled by a Central-Atlantic type of steam locomotive, was stopped in the tunnel under Sixty-sixth street, on a 0.5 per cent upgrade, because of some mishap to the engine. Following it was a train of seven standard day coaches, shop-bound and hauled by an electric locomotive, which promptly coupled on to the leading train, and without any assistance from the steam locomotive, which was dead, started the entire load of sixteen cars and two locomotives, weighing nearly 1,000 tons, with good acceleration, and made the run up a 1.02 per cent grade, a half-mile long, at satisfactory speed and without difficulty.

The New York Central equipment has been developed under extraordinarily difficult circumstances, but already 305 train movements, representing 86 per cent of the present total of the New York Central and Harlem trains, both locomotive-drawn and multiple-unit, are

operated electrically. The aggregate delay has been less than with the old steam service, a fact particularly noticeable in times of snowstorms. The main station output for twenty-four hours is but about 65,000 kilowatt hours, and when the batteries are in service but one steam unit is required at time of maximum load.

The New Haven alternating current-direct current locomotive, built by the Westinghouse Electric and Manufacturing Company, is of the two-axle free bogie type, the bogies being pivoted under and transmitting their effort through the frame which carries the cab, in which are mounted the transformers, blowers, rheostats and controllers (pl. II). On each truck are mounted two spring-supported motors, each complete within itself. The armatures are carried on quills, terminating in spiders at each end, which engage eccentrically wound springs inclosed in pockets in the main drivers.

The rigid wheel base is 8 feet, the total wheel base 22 feet, and the length over all 37 feet. The weight of the locomotive is 93 tons, having been raised considerably over early expectations. It has an hour rating, on the usual standard, of 1,000 horsepower when operated at 25 cycles, but is equipped with blowers to raise the average capacity. It is intended to handle a 200-ton trailing load at schedule, with some margin of performance.

Although built primarily for operating directly from 11,000-volt single-phase alternating current, these locomotives must operate also from the 650-volt direct current while on the Harlem tracks. They, therefore, have additional control provision, and besides the double-pantograph collectors, have contact shoes, those on the side being arranged for lifting by air pressure on account of limited clearances on a part of the run.

The motor armatures are wound for operation at a normal maximum of about 250 volts, and hence are connected in permanent series of two, while the field circuits are arranged for each pair of motors in a separate group, and for series-parallel grouping independently of the armature circuits, to provide for the varying flux in alternating-current and direct-current operation. Of course, the two motor groups can be connected for series-parallel operation with direct-current supply, but with the disadvantage of using about double the amount of current at slow speeds that is required when four motors, each wound for the full potential, are in series.

The first of these machines, pulling a short train, made entry into the Grand Central Station on May 11, 1907, and in a short time the operation of equipment should be under service test.

In order to combine the possibility of single-phase alternating-current current transmission at high voltage by overhead trolley, and the unquestioned advantages of the direct-current motor, it has several times been proposed to introduce between the line supply and the

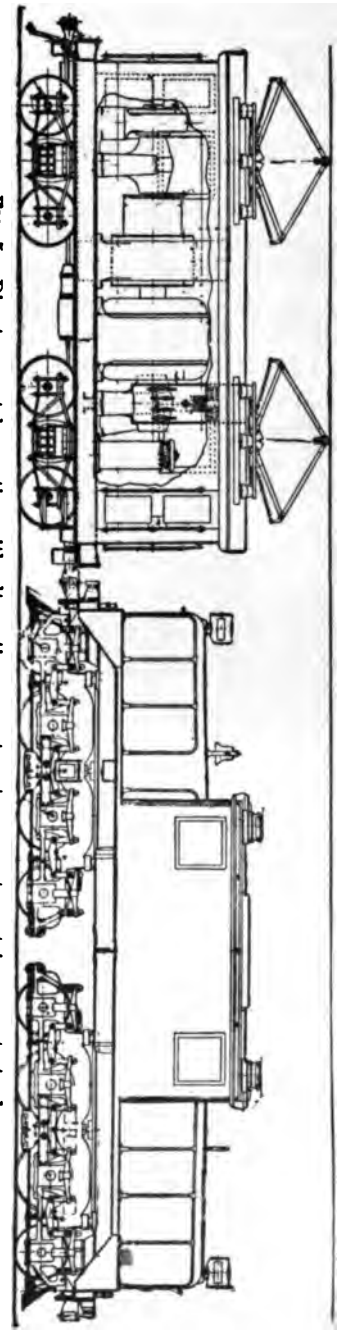


Fig. 5.—Direct-current locomotive with alternating-current motor-generator set in separate tender.

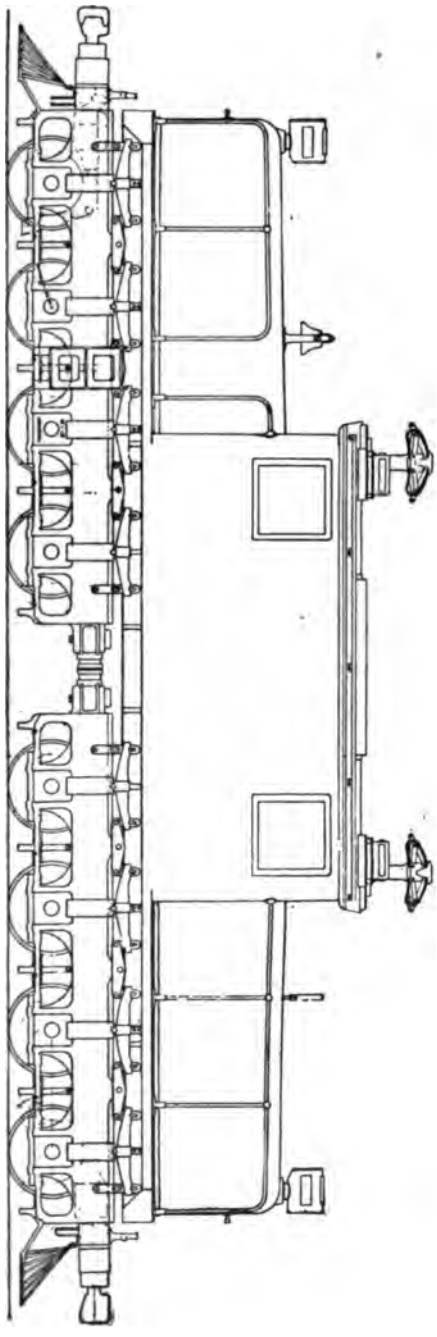


Fig. 6.—1,800 h. p., 1,500-volt bogie truck locomotive, gearless motors. Weight, 126 tons.

motors a motor-generator set, comprising an induction motor taking current directly from the line, and driving a continuous-current generator to supply the motors, this converting set being carried in the main cab, with provision made for the extra weight by bogie trucks at each end, or in an independent tender taking the place of the steam tender in existing steam practice (fig. 5). Of course this is the introduction of a moving substation individual to the locomotive which is operated by it, and makes the latter subject to all the idiosyncrasies of the intermediate apparatus, besides laying up an enormously expensive machine in case of any special trouble. Where the motor-generator set is carried in a separate tender, this disablement only cuts out a part of the equipment, which can be replaced by another like part, but in any case it is debatable whether such a moving substation offers any advantage over the stationary one.

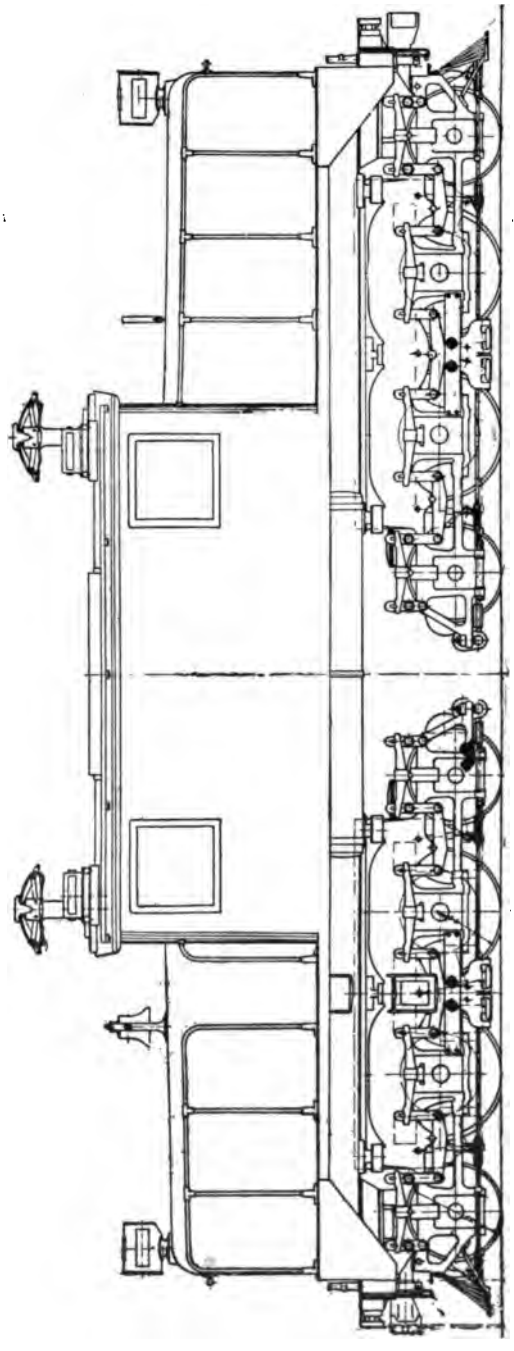


FIG. 7.—High-speed bogie truck direct-current locomotive, gearless motors. Weight, 80 to 110 tons.

Some time since I made a very careful investigation of the possibilities of direct-current gearless and geared motors (fig. 6), the former of the bipolar *type,* for identically the same service, a very severe one.

Both machines are of the four-axle bogie-truck type, the trucks being linked together. The geared locomotive weighs 93 tons and the gearless 126 tons, but the weight per axle is well within the usual allowance. On each truck are four motors, connected two in series, to be operated at a maximum line potential of 1,500 volts. The geared motor construction is of the usual standard, but fitted with commutating poles, while the gearless machine has modified bipolar motors of the New York Central type.

A comparison of the efficiency curves of the two machines is interesting, these showing for each from 87 to 88 per cent on a five-hour load, and falling only to 83 per cent with 50 per cent increase, while at half this load the efficiency of the gearless machine is much higher than that of the geared. Some adequate idea of the capacity of the gearless machine may be gathered from a statement that it will maintain a drawbar pull of nearly 25,000 pounds at a good rate of speed for several hours continuously, and with natural ventilation. These extraordinary characteristics would, for the class of service for which these machines were considered, amply warrant the additional weight because of the simplicity of the gearless machine.

A very promising type of machine (fig. 7), embodying many of the good features of those which had preceded it, is now under construction for use either on direct current or with a motor-generator set supplied from an alternating-current trolley. This machine is of the four-axle free bogie type, the drawbar pull being taken through the main frame. On each truck, and forming an integral part with it, are two bipolar gearless motors driving the middle pair of axles, and at either end of each truck is a pair of leading wheels of smaller diameter, which have a limited, spring-resisted side play. The normal wheel base of each truck is 12 feet, the total wheel base 32 feet, and the length over all 36 feet. This machine should be capable of an almost unmatched speed and freedom in following irregular curvatures, and with special ease of track approach.

The various locomotives thus briefly described are but a fraction of those proposed by various makers to fit particular conditions and types of apparatus. Their construction does not, in many particulars, meet the preconceived ideas of some steam-locomotive builders, with whom a high center of gravity and all the weight possible carried on springs is a cardinal principle, and a very correct one when we consider the necessities of the steam locomotive. The electric locomotive has a lower center of gravity, that of the New York Central machine being about 44 inches, the New Haven 51, and the Ganz probably somewhat higher, while that of the steam locomotive is sometimes as high as 73 inches. The electric machine, therefore, will have less tendency to topple over, but a greater resultant side pressure in case of irregularity of track when entering a curve, or running on an

irregular track, than its rival, a larger portion of whose weight heels over and increases the vertical pressure on the rail. Careful investigation, however, carried on through many sources, seems to indicate that with electric motors properly guided any increased tendency to side thrust is more than compensated for by certain other advantages. * * *

Train control and operation.—Restriction of operation in an electric system to methods in vogue with steam operation would be a useless throwing away of one of the greatest possibilities of improvement in train operation where passenger service is heavy and terminal facilities congested. Ten years ago I inaugurated on the South Side Elevated of Chicago a new system of train control, which permitted the aggregation into trains of any number of independently equipped motor cars, and dead cars if desired, and their control from either end of any car, irrespective of train make-up. This system, now known the world over as the "multiple-unit" (fig. 6), has made such advance that it is now generally recognized and adopted as the best method of handling trains wherever service is crowded and high schedules are required.

The essential result accomplished by this system is increase of capacity, by providing high power equipments, proportional to the length of the train, increased schedules and density of train movement, the lowest maximum speeds for any given schedule similarity of equipment, reduced switching and signal movements, increased safety, and generally the utmost independence and facility of operation. Whatever tentative plans may for the present be adopted, I believe that it is inevitable that all local and suburban passenger service on electrically equipped railways requiring train operation will be eventually conducted on the multiple-unit plan, and its use will spread over a continually increasing area, even to the operation of passenger cars run over divisions of considerable length.

Storage batteries.—The use of the storage battery in connection with electric railway operation is a proposal concerning which much may be said, for and against, depending largely upon what value one attaches to restriction of peak loads on moving machinery and to insurance. That it has been and is being used successfully in connection with direct-current equipment of moderate potential admits of no dispute, and it has been stated that it is equally available for alternating-current installations. This latter claim is misleading. On direct-current systems the principal function of a battery is that of an equalizer. If installed at a central or substation it is usual to provide boosters to govern the charging and discharging. These, however, are only of differential watt capacity, and while they are necessary for regulation, it is perfectly possible to use the battery in some emergencies by direct connection with the line.

With an alternating-current system, the battery at a substation plays an entirely different rôle. It must be charged by a direct-current generator driven by an alternating-current motor, and in discharging drives the alternating-current motor as a dynamo through the direct-current generator acting as a motor. In addition to the introduction of moving machinery in an alternating-current substation, its watt capacity must be equal to that of the full discharge of the battery, and the latter can have no function in supplying current to the working conductor except through the medium of two rotating machines of large capacity.

Use of step-up and step-down transformers.—Where the distance is not great, as on the present proposed limited operation of the New Haven road, both step-up and step-down transformers have been omitted, and the 11,000-volt trolley line is supplied from the station switchboard. This means direct connection between an extended system of overhead working conductors and generators operated at high potential, with one side grounded, with, of course, whatever protection lightning arresters can provide. Such are the vagaries of lightning and the uncertainty of the very best arresters, that I cannot but feel that this practice, which subjects costly generating equipments to direct lightning attack and special grounding stress, will not obtain to any great extent; for the possibility of laying up a complete unit of great capacity, steam engine as well as generator, because of a lightning flash or accidental ground, is too great a penalty to pay for eliminating transformers, and is a special handicap upon the possibilities of transmission.

It is certain that standardization should be directed to the construction of generators. Any material increase of potential above that now common means reduced capacity and efficiency, increased danger of breakdown, and greatly increases individual cost, to say nothing of the capitalized risk of failure. Quite aside from the question of cost and efficiency, air cooling, the only possible method for generators, manifestly cannot be safely carried above that which is tolerable for static transformers, which, when wound for the higher potentials, are invariably oil-cooled. Therefore I expect to see standardization of generator potentials, the pressure being stepped up by transformers to whatever transmission potential is necessary, and then stepped down to the working pressure on the trolley wire if alternating current be used, or to a lower pressure and converted if direct current be used.

The transformer, per se, is the simplest and most flexible device for changing alternating-current volume and pressure, and its moderate cost and high efficiency, taken in connection with the like elements of moderately high potential generators, will leave the total cost and efficiency of generating equipment roughly the same. There will be

the added very great practical advantage that the generators not only work at lower potentials, but on closed metallic circuits, are removed from direct contact with working conductors and earth, and have interposed between them and the line at least one set of static transformers, which practical experience has shown to be one of the best generator safeguards against lightning, and which, if broken down, do not involve large and costly units nor wholesale sacrifice of capacity on roads where the adoption of electricity is warranted.

General cost comparison of direct-current and single-phase alternating-current systems.—I have made many comparative analyses, involving millions of dollars, and I have found that where equal permanence of installation is provided for, and equal ultimate as well as average duty, there is not on demonstrated facts a wide variation in the initial cost of plant.

Ordinarily, the signal systems used on railroads will have to be changed at considerable cost. Fortunately, methods have been developed which permit the use of all the rails for the main return circuit by using a special alternating-current circuit for operating the signals. Where the tracks are used for direct-current return, reactance bonds are inserted which permit the flow of the direct current, but resist that of the alternating signal current. Where the tracks are used for alternating-current operation, and are likewise subject to the flow of direct currents, the signals must be operated by alternating currents of high frequency through apparatus which is inoperative to currents of low frequency or to continuous currents.

Field of the single-phase alternating-current motor.—It would be idle to deny, and I have no wish to belittle the good work done and the results achieved in the development of the single-phase motor, just as it would be equally unwise to ignore what has been done in polyphase and direct-current work. It seems to me that the present principal field of usefulness of the single-phase system is on roads of considerable extent which operate an irregular and sparse traffic, and where only a moderately expensive, or what may be called a second-class overhead construction, which will keep down the ratio of line investment to that of the balance of equipment, is tolerable. As one departs from this condition, adopts more permanent construction, and faces the problems of denser traffics and higher capacities, any advantages of the single-phase system disappear, and the superiority of the direct-current equipment, with such improvements as are in sight, becomes manifest. But whatever may be the future of single-phase operation under the conditions stated, any present claim for it as the preferable equipment for congested service demanding high schedules and great capacity is not worth a moment's thought, for in this field it can not touch the direct-current system.

NEW YORK CENTRAL MULTIPLE-UNIT TRAIN.

In closing, let me again remind you of the probability, nay certainty, that there is at present no single system which can be selected as best for all purposes, but, rather, that a wide and increasing use of each will be created, and in the majority of cases a compromise selection of the best elements of alternating and direct current practice will obtain.

While there are many things in railroading which have been standardized, and others which can now very properly be, and which of themselves do not militate against the independent judgment of operating railway officials in matters individual to their own systems, I think it is certain that these same officials will in the future, as in the past, consider the problems involved in a change of motive power from steam to electricity from an individual standpoint, and that they will demand from manufacturers, as well as from their engineers, all possible freedom from restricton, exercising in a large measure their own judgment as to the adoption of any system. I see no practical necessity to formulate conclusions by averaging conditions, and I can not conceive the responsible officers of any trunk-line road being guided in their determination of what seems best for their own requirements by consideration of what some road thousands of miles removed in location, and enormously differing in operating conditions may do.

In any case, the most satisfactory system will be that one which will permit of continuous all-round operation under such conditions as will utilize to the utmost all the beneficial features of electric application. If any one system can be demonstrated to meet these conditions better than all others, then that system will become preeminent, no matter what standards may have been adopted or recommended, and no matter what our preconceived prejudices may be.

RECENT CONTRIBUTIONS TO ELECTRIC WAVE TELEGRAPHY.[a]

By Prof. J. A. FLEMING, M. A., D. Sc., F. R. S., M. R. I.,
Pender Professor of Electrical Engineering in the University of London.

The achievements and possibilities of wireless telegraphy have not yet ceased to interest the public mind. In less than ten years from the practical inception of that form of it conducted by electric waves, it has developed into an implement of immense importance in naval warfare and maneuvers. It has provided a means of communication between ship and shore which has added greatly to the safety of life and property at sea. It has so far altered the conditions of ocean travel that great passenger liners, separated by vast distances on stormy seas, speak to each other through the ether with far-reaching voices, and are never out of touch with land during the whole of their voyage from port to port.

You are doubtless aware that it is now the usual thing for an Atlantic liner, equipped with long distance receivers, to be in communication with either the Marconi stations at Poldhu in England or Clifden in Ireland, and that at Cape Cod in the United States throughout the voyage, and at the same time to exchange messages not only with the other shore stations when passing, but with a score or so of sister vessels during the journey.[b]

On board many of the Cunard liners small daily newspapers are published containing the latest news of the day sent by wireless telegraphy from both coasts.

Every important navy in the world has now adopted it in some form as an indispensable means of communication. In our own navy,

[a] Paper read before the Royal Institution of Great Britain at its weekly evening meeting, Friday, May 24, 1907. Reprinted, by permission, from the Transactions of the Royal Institution.

[b] The Cunard liner *Lucania*, which arrived March 18, 1907, at Liverpool from New York, reported that she was, when in mid-Atlantic, in communication by wireless telegraphy with Poldhu, in Cornwall, and Cape Cod, in the United States, at the same time. During the voyage she spoke with thirty-two North Atlantic steamers, and with twenty-four of these she had wireless communication.

Admiral Sir Henry Jackson, to whom the country is so much indebted in this matter, informs me that every ship above the size of a torpedo boat is or will soon be fitted. Large battle ships carry fairly high-power transmitters for long-distance work. The Admiralty are satisfied that this method of signaling is of the greatest utility, and there is no need to remind you of the evidence of this furnished in the recent Russo-Japanese war. No modern liner or large passenger vessel is now complete without a wireless telegraph equipment, and an elaborately organized system of communication has been created by the Marconi Company in connection with this marine telegraphy.

Concurrently with this practical development of the art, much scientific investigation has been conducted, having for its object the elucidation and measurement of the various physical operations involved, as well as further improvement. There comes a time in the history of every applied science when the ability to measure precisely the effects concerned is a condition of further progress. It is this alone which enables us to test our theories, or hold in leash hasty opinions as to the possibilities of the invention.

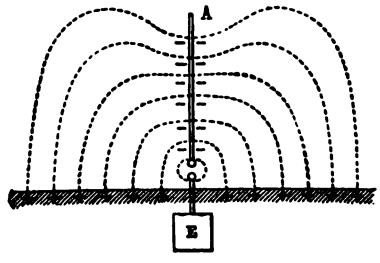


FIG. 1.—Lines of electric force round an antenna before discharge.

In considering, then, during the present hour some of the recent contributions to this new telegraphy, we may pay a moment's attention to the nature of the things or effects in it which can be measured. An essential element in all electric wave telegraphy is the elevated insulated wire or wires called the antenna, in which high frequency electric currents are set up, and from which the electric waves radiate. Consider a long vertical wire, insulated completely from the earth and charged with electricity. (See fig. 1.) There must be somewhere on the surface of the earth near by a charge of opposite sign. If the wire is negatively charged, then, on its surface, there is, according to modern views, an excess of negative ions or electrons, and on the ground surface round the wire there is a deficiency, that is, there is a positive charge. Furthermore, in the interspace around the rod there is a state of strain of some kind distributed along certain curved lines, commonly called lines of electric force. From one point of view these lines may be regarded simply as a convenient mode of delineating the direction of the strain, having not more material reality than lines of latitude and longitude. There are, however, some reasons for considering that they *do* possess an actual physical existence, and that they are a necessary part of the mechanism of atoms and

electrons.[a] They have a strong resemblance in many ways to the vortices or vortex lines, which can be created in a fluid. Moreover, just as vortex lines in a fluid can be self-closed or endless, or else terminate in little whirlpools on the free surface of the liquid, so lines of electric force can form either closed loops, or else have their ends terminating on opposite charges of electricity, that is, on an electron at one end and the positive charge of an atom, whatever that may be, at the other end. Suppose, then, that the rod is suddenly connected to the earth at the bottom end by allowing it to spark to the earth. Its electric charge rushes out, that is, the excess or deficit of electrons on its surface disappears, and this movement of electricity constitutes an electric current flowing into or out of the rod from the earth. The electrons, however, possess inertia or mass, hence when they rush out of the rod into the earth they not only discharge it, but overdo it, and leave the rod with a positive charge. They then rush back again, and the process repeats itself, and we thus obtain a rapid ebb and flow of electricity into and out of the wire, called a series of electric oscillations. Each rush, however, is feebler than the last, and therefore the oscillations decay away or, as it is termed, are damped. The energy represented by the initial charge is frittered away, partly owing to collisions of the electrons and atoms in the rod and spark during the movement, and partly because the electron radiates or communicates its kinetic energy to the medium when it is accelerated or retarded.

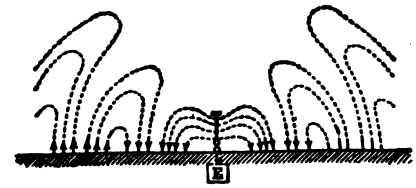


FIG. 2.—Diagrammatic representation of the detachment of semiloops of electric strain from a simple Marconi antenna.

We have next to attend to the effects taking place outside the rod or antenna. As the negative charge disappears from the rod owing to the removal of the excess of free electrons from its surface the ends of the lines of electric force which abut on it and stretch between it and the earth glide downwards along the rod and end by forming a semiloop of electric force or strain with its ends or feet resting on the earth. (See fig. 2.) This arises from the facts that the lines of

[a] *Cf.* Faraday. "Experiment[illegible] ectricity," Vol. III, series XXIX, 3273, 3297, and [illegible] uguetic Force." Faraday used the express[illegible] reality as distinguished f[illegible] Thoughts on Ray Vibr[illegible] that light may be a[illegible] homson. "Electri[illegible] of lines of ele[illegible]

force exercise a lateral pressure on each other, whilst lengthways they are in a state of tension, and also that lines of electric strain can not exist inside a conductor such as a spark. Hence when the spark happens, the lines which a moment ago stretched across the spark gap disappear. There is then an unbalanced pressure on the remaining lines which are thus squeezed in toward the gap and deformed, so that they finally extend, not from rod to earth, but from two adjacent places on the earth and form a semiloop.

But, as above explained, the rod does not simply become discharged. Owing to the inertia of the electrons when they rush out, they more than discharge the rod, they overdo it and leave it positively charged. This, then, implies that a fresh system of lines of electric force grows up between the earth and the rod, and the first formed set of semiloops is pushed outward. Then the process is repeated as the oscillations of the electrons in and out of the rod die away, and in the space around we have a system of semiloops of electric force being pushed outward in every direction as shown in the diagram in fig. 2.[a]

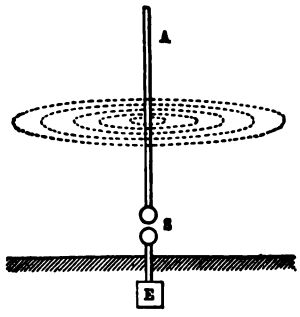


FIG. 3.—Lines of magnetic force round an antenna during discharge.

There is, however, another factor involved in the process. The movement of the electrons into and out of the rod constitutes an alternating electric current and this is accompanied by the production of an alternating magnetic field, the direction of which is represented by a system of concentric circles with their centers on the antenna (see fig. 3). When the current in the rod is reversed in direction, the field is not reversed at all parts of space instantaneously, but the reversal is propagated outward with the speed of light. Accordingly, the electric oscillations in the antenna create periodic variations of magnetic force and electric force in the space outside. At points near the earth's surface some way from the rod the magnetic force is parallel to, and the electric force perpendicular to the surface of the earth or sea. Experience shows that electric wave telegraphy

[a] In referring to lines or semiloops of electric force as moving through space, we do not necessarily mean to imply that each line is earmarked so that it preserves an individual identity. All that actually happens at any point in the field is a periodic oscillation or cyclical change in the electric and magnetic force at that point. This, however, is repeated successively from point to point, and we may hence speak of the line of force as moving forward just as we speak of a surface water wave moving forward, when in reality the only movement in the latter case is a small up and down motion of the water at each place, or at least a circular motion of no very great extent.

over any large distances can not be conducted unless the antenna is so placed that the electric force is perpendicular to the surface of the earth or sea.

At any distance from the antenna, and at any one spot, the magnetic and electric forces are therefore periodically varying in magnitude, and owing to the finite rate of propagation of the forces through space we find that at certain equispaced intervals these forces are similarly reversed in direction at the same instant.

When we speak of the length of the electric waves we mean the shortest distance which separates two adjacent places at which either the electric or magnetic force reverses direction in the same way at the same instant. In wireless telegraphy the length of waves employed may vary from 200 to 300 feet to many thousands of feet or several miles. The determination of this wave length is a practically important matter, and accordingly instruments have been designed specially for its measurement by Dönitz, by Professor Slaby, and by me. I have ventured to name my own appliance for measuring long electric wave lengths, a *cymometer*.[a] The importance of the measurement is as follows: We know that the properties of short electric waves constituting light and radiant heat depend upon their wave length, and that some bodies are opaque to light waves but transparent to heat waves. So in the case of the much longer ether or electric waves used in telegraphy, the ease with which they pass through buildings, forests, and even mountains or cliffs, or round the earth's curved surface is determined by their wave length. Waves of one or two hundred feet in length are considerably obstructed by the closely packed houses in a town, but much longer waves go easily through them. The measurement of the wave length is made to depend upon the fact that there is a simple relation between the velocity of these waves (which is the same as that of light), the periodic time of the oscillations in the antenna, and the wave length as expressed by the formula *wave length* = *velocity* × *periodic time*. Since the velocity is nearly 1,000 million feet per second, the wave length in feet is easily found, when we know the time period of the oscillations in the antenna. This last quantity can be found by placing near to the antenna a circuit in which secondary electric oscillations can be sympathetically induced by those in the antenna. For this purpose we must have a circuit which possesses the two qualities of capacity and inductance. This is secured by joining in series some form of Leyden jar or condenser and some form of spiral wave or inductance. Moreover, we must have the means of varying this capacity and inductance, so as to bring the cymometer circuit into tune, as it is called,

[a] See Proc. Roy. Soc., Vol. LXXIV, p. 490, 1905. On an Instrument for the Measurement of the Length of Long Electric Waves. Also Phil. Mag., June, 1905, on the Applications of the Cymometer.

with the antenna. Every such circuit containing capacity and inductance has a natural period of electric oscillation, resembling in this respect the time of swing of a mechanical system composed of a heavy body suspended by an elastic spring.[a] In my cymometer the condenser part consists of one to four sliding tubes, each consisting of a pair of brass tubes, separated by an ebonite tube. The outer tubes can slide off the inner ones and so vary the capacity. The inductance consists of a long spiral of copper wire, and the circuit is completed by a thick copper bar. Matters are so arranged that when the outer tubes are drawn off the inner tubes so as to vary the electrical capacity, the effective amount of the spiral included in the circuit is simultaneously varied in exactly the same proportion. To determine when the time period of the cymometer circuit is in agreement with that of the antenna, I use a neon vacuum tube. Some three years ago I found that such a tube was extremely sensitive to a high frequency electric field, being caused to glow brilliantly when subjected to its action.

You are already familiar with the beautiful method discovered by Sir James Dewar for obtaining neon from atmospheric air by the use of charcoal at very low temperatures, and tubes filled with rarefied neon prepared by his process are able, as I have shown, to serve important purposes in connection with wireless telegraphy.

In the cymometer a neon tube is connected to the opposite coatings of the condenser. If then the cymometer bar is placed near to the lower part of a transmitting antenna, and we slide along the outer condenser tube, thus varying the capacity and inductance of the instrument, provided it has a suitable range, a position will be found in which the neon tube glows brightly. The cymometer is equipped with a scale which shows for every position of its handle the corresponding frequency or time period, and the related wave length. Hence the simplest operation, which a child can perform, serves to determine in one instant the frequency of the oscillations in the antenna and the wave-length of the radiated waves. I have devised instruments of this type covering the whole range of wave-length measurement from 50 to 100 feet up to 20,000 feet or more. An instrument of the same kind, but with a more sensitive oscillation detector than a neon tube, can be used to measure the wave-length of waves being received on the antenna. The cymometer has other uses besides wave-length measurement. One of these is to draw a resonance curve and thence reduce the rate of decay of the oscillations in a train and their number. In a train of oscillations the time period occupied by each oscillation, whether of current or potential, is the same, but the am-

[a] If the capacity C is reckoned as usual in microfarads, and the inductance L in centimeters, then the time period T of the oscillation is given by the formula $T=\sqrt{CL}/5033000$.

plitudes die away in geometric ratio. Hence the ratio of two successive amplitudes or oscillations is constant, and the natural logarithm of this ratio is called the *decrement*. We can determine this decrement when we know the frequency of the oscillations in the primary circuit and the current induced in any secondary oscillation circuit, placed near to the first, when the latter is in exact syntonism, and also slightly out of syntonism, with the primary. Employing a formula of Bjerknes, we can find the sum of the decrements D and d of the primary and secondary circuits by the formula

$$D + d = \pi\left(1 + \frac{n}{N}\right)\sqrt{\frac{a^2}{A^2 - a^2}}$$

where a is the current in the secondary circuit when it is tuned to a frequency n, and A is the maximum current when the secondary circuit is tuned to agree with the frequency N of the primary circuit. For this purpose I modified the cymometer by including in the bar

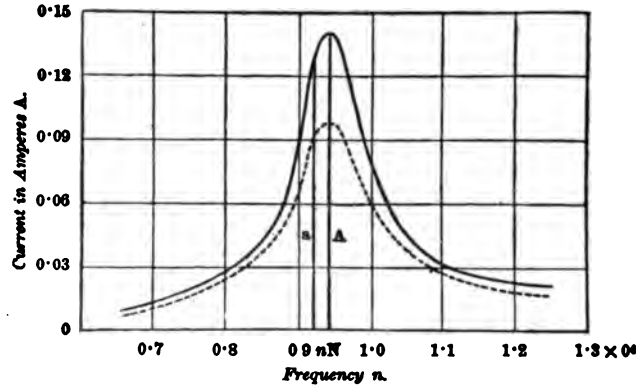


FIG. 4.—Resonance curve of loosely coupled oscillatory circuit.

two fine resistance wires, against one of which a sensitive thermo-junction of iron and bismuth is attached. This enables me to measure the value of the current in the cymometer bar. The process of measurement is then as follows: We place the cymometer alongside the antenna and slide along the handle slowly, thus altering its time period or natural frequency. We observe the current and frequency, and plot a curve called a resonance curve showing the secondary or cymometer current in terms of the frequency. (See fig. 4.) This curve rises to a maximum value, sometimes very sharply, the maximum corresponding to the condition of exact syntonism between the antenna and cymometer circuits.[a] From the curve we can determine

[a] If the damping of the secondary circuit is small, as it is in the case of the cymometer circuit, then the resonance curve is very sharply peaked or rises quickly to a maximum when the primary oscillations are feebly damped, provided always that the "coupling" or mutual inductance of the two connected circuits is small.

the sum of the decrements of the cymometer and antenna. A second experiment made with a known additional resistance inserted in the cymometer bar enables us to eliminate the decrement (D) of the cymometer itself, and thus find that of the antenna alone. When

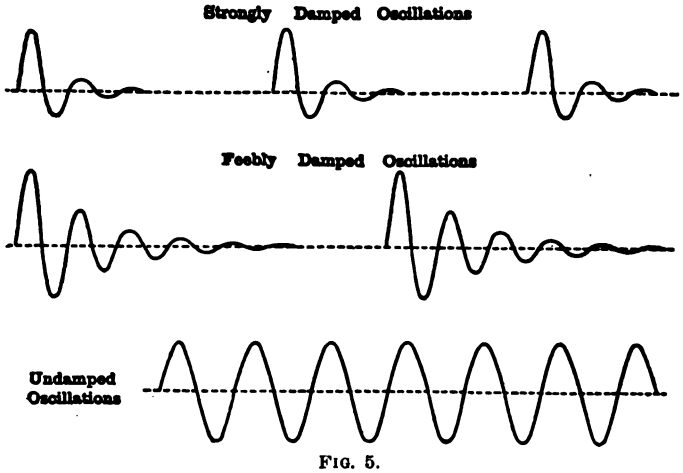


FIG. 5.

this is done we know what percentage each oscillation in the antenna is of the previous one. Suppose we agree that when the oscillations have decayed away to 1 per cent of their initial value, the train shall be considered to be finished, then another simple formula $M=(4.605+D)/2\ D$ enables us to find the number of complete oscillations M in a train when we know the decrement D.[a]

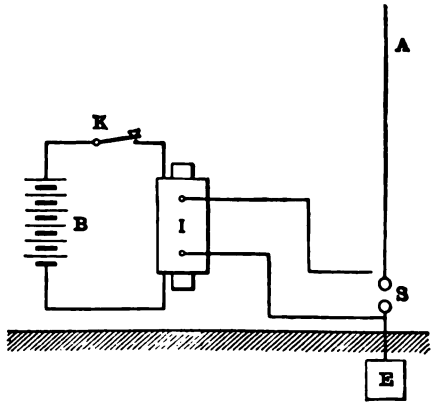


FIG. 6.—Antenna emitting strongly damped telegraphic electric waves.

Electric oscillations are classified into highly damped, feebly damped and undamped varieties corresponding to few, many and infinite oscillations in a train. (See fig. 5.) In electric-wave telegraphy we have various kinds of transmitters or wave-makers which are intended to create these types of oscillation. In the first case, if we set up an antenna and connect the lower end to one of the spark balls of an induction coil, the other being to earth, we have an arrangement which produces highly damped oscillations and waves. (See fig. 6.) This is due to the fact that since the capacity of the antenna itself is small,

[a] See "The Principles of Electric-Wave Telegraphy," Fleming, p. 167.

the energy which can be stored up in it and liberated at each spark discharge is also small, at most a fraction of a foot-pound or a few foot-pounds. Hence it is rapidly frittered away by resistance and in radiation, and the oscillations are few, say half a dozen or so, and highly damped. If, however, we form an oscillation circuit consisting of a large condenser, inductance and spark gap we can store up a larger amount of energy and liberate this suddenly across the spark gap at each discharge. (See fig. 7.) If, then, these oscillations are made to induce others in a directly or inductively connected antenna, we can liberate the energy as radiation, and having a larger store to draw upon create longer trains, say of 20 to 100 more feebly damped oscillations.

Corresponding to these types of transmitter there are various suitable forms of receiver. With a highly damped radiator we must use some form of wave-detector, such as a coherer, which is chiefly affected by the first or maximum oscillation, and this must be inserted in a receiving circuit which is easily set in oscillation by a single or at most a few electromagnetic impulses. On the other hand, this renders the receiver more liable to disturbance by vagrant electric waves due to atmospheric electricity, or other transmitters if of sufficient strength.

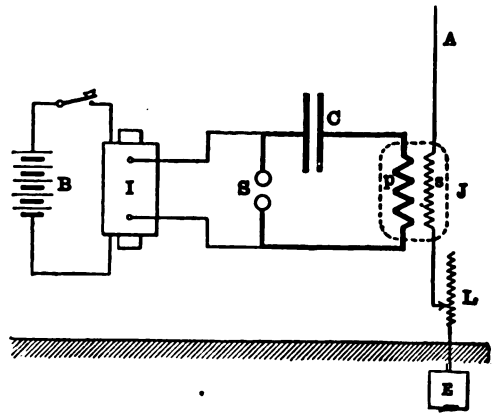


FIG. 7.—Antenna emitting feebly damped telegraphic electric waves.

If, however, we employ a feebly damped radiator emitting long trains of waves, say 20 to 50 waves, we can make use of a stiffer receiver circuit, that is one containing a good deal of inductance, and a detector such as Marconi's magnetic detector, which operates under the action of feeble but oft-repeated and properly timed impulses. We have then the advantage that the receiving circuit can be made far less sensible to non-syntonic or isolated impulses unless these are of extreme violence.

Again, there are certain forms of detector—such as the thermal and one of my own, to be described presently—which are affected by the product of the mean-square value of the oscillations during a train and by the number of trains per second. Hence, in this case the effect on such a receiver at a given distance under the same conditions will be increased by increasing the number of trains of oscillations per second, as well as by diminishing damping in each train.

It was therefore foreseen that we should gain some advantage by the use of undamped trains if some form of electric radiator could be found emitting waves continuously, like the steady note of an organ pipe, rather than sounds like intermittent blasts on a trumpet or blows on a drum. There are at least three ways in which these undamped oscillations can be created. The first is a mechanical method, viz, by a high-frequency alternator. Assuming we possess an alternating current dynamo giving a current of a sufficiently high frequency, we can connect one terminal to earth and the other to a radiating antenna, and then on setting the machine in operation high-frequency undamped currents would be created in the antenna, and corresponding waves radiated. To secure the best results, it is necessary, however, to syntonise the free-time period of the antenna circuit and the natural frequency of the alternator. The chief difficulty, however, is to construct a machine which shall give alternating currents of sufficiently high frequency and voltage with sufficient power and current capacity. Sixteen or seventeen years ago Prof. Elihu Thomson and M. Tesla built dynamos giving an alternating current of 10 amperes at a frequency of 10,000 to 15,000, and an output of about 1,000 watts. Mr. Duddell exhibited to the Physical Society, in April, 1905, an alternator capable of a frequency of 120,000, but its power output was not more than 0.2 watt. I have on the table a small alternator made by Mr. S. G. Brown, giving an alternating current having a frequency of 12,000, an E. M. F. of 20 volts, and a power of about 50 watts. Professor Fessenden has recently given a description of an alternator made for him having a frequency of 60,000, with an output of 250 watts, running at a speed of 10,000 R. P. M., and giving an E. M. F. of 60 volts. Since steam turbines of the Laval type are now made to run at 500 revolutions a second, it is not difficult to construct an inductor alternator having a frequency of 50,000 to 100,000. Such a type of alternator has, however, always a large fall in terminal potential difference if called upon to give out current. For this reason, a type of machine without iron in the armature is to be preferred, but then it becomes more difficult to balance the moving parts for very high speeds. In spite of some attempts, the difficulties of making and driving a high-frequency and high-potential alternator of any considerable output, say 10 kilowatt size, have not yet been overcome. Even if we could secure a frequency of 50,000, this corresponds to a wave of 4 miles in length, and special antenna arrangements are necessary to radiate and receive such waves. Hence the alternator method of electric wave production will certainly not supersede the spark method, although in some cases it may be practicable and useful.

In the next place we have the electric arc method, to which so much attention has lately been directed, employing a continuous current arc with a condenser and inductance placed in series across the terminals of the arc. As in many other cases, the seeds of this invention were sown in the form of discoveries by several workers. In July, 1892, Prof. Elihu Thomson filed a United States Patent No. 500630, in which he proposed a method for creating high-frequency alternating currents by connecting a condenser and inductance to a pair of spark balls and this spark gap was also connected through two other inductances with a source of continuous current supply such as a storage battery or dynamo. (See fig. 8.) An air blast or magentic field was employed to continually extinguish the continuous current arc formed. The operation of the arrangement was thought to be as follows: When the arc is blown out, or before it is formed, the condenser is charged by the dynamo.[a] When the arc is reëstablished the condenser is discharged with oscillations. In the above specification nothing is said about the use of a continuous current arc between

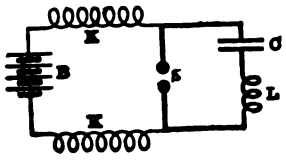


FIG. 8.—Elihu Thomson's method of producing oscillations.

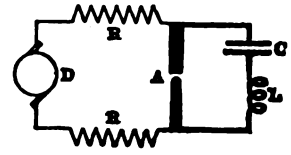


FIG. 9.—Duddell musical arc.

carbon poles, but Professor Thomson asserts that oscillations with frequency up to 50,000 could be obtained. In 1900 Mr. Duddell showed that if a suitable condenser and inductance was shunted across the poles of a continuous current arc formed with solid carbons, high-frequency alternating currents were set up in the condenser circuit and the arc emitted a musical sound. (See fig. 9.)

Much discussion subsequently took place as to the causes of the effect and as to the highest frequency of oscillation it was possible to secure by this method. Duddell and others based their explanation of the phenomenon upon the known fact that a small decrease in the current through the carbon arc is accompanied by an increase in the

[a] An interesting and not very dissimilar device has recently been described by Mr. S. G. Brown. He employs a revolving aluminum wheel against which a copper spring presses lightly. The spring and wheel are connected through an inductance and resistance with a source of direct current supply, and also by a circuit consisting of Leyden jar in series with a coil of wire. When the wheel revolves an arc is formed at the loose contact, and high-frequency oscillations are set up in the Leyden jar circuit. (See The Electrician, November 23, 1906, Vol. LVIII, p. 201.)

potential difference of the carbons. The continuous arc with solid carbons was said therefore to have a negative resistance.[a]

The explanation of the manner in which the continuous current arc maintains undamped oscillations in the condenser circuit is then as follows: If a condenser and inductance are shunted across the arc, the condenser begins to be charged, and this robs the arc of some current. This change, however, raises the potential difference of the carbon poles and the charging of the condenser therefore continues. When the condenser is full the arc current is again steady. The condenser then begins to discharge back through it, and this increases the current through the arc and therefore decreases the potential difference of the carbons. The condenser therefore continues to discharge. The action resembles that by which the vibrations of the column of air in an organ pipe controls the behavior of the jet of air from the mouth which impinges against its lip, forcing the jet of air alternately into and outside the organ pipe, and so maintaining stationary oscillations in it. The jet of air from the mouth of the pipe corresponds to the continuous current arc, the closed or open pipe associated with it is a resonant circuit and corresponds with the condenser and inductance.

Consider the state when the oscillations have been set up in the condenser circuit. We must assume that there is a stream of electrons from the negative terminal of the arc making their way across the interspace to the positive terminal. If, then, we consider the state at the instant when the condenser has reversed its charge, so that the coating connected to the negative arc terminal is positively charged, we see that there is a tendency for the stream of electrons to enter the condenser and supply the deficiency represented by the positive charge on that plate. They are, so to speak, sucked into the condenser. Accordingly this action either annuls or reduces the current in the arc. When the condenser is charged to the potential difference then existing between the terminals of the arc, no more electrons enter it, and they then all travel across the arc. This increase in the arc current is accompanied by a fall in the electronic density difference, or the potential difference of the arc terminals, and the condenser then begins to discharge across the arc, and still more reduces this potential difference. Owing to the inductance in series with the condenser, or in other words in consequence of the kinetic energy of the moving electrons, the condenser is not only dis-

[a] The term negative resistance is a very inappropriate term. It is better to call the curve for an electric arc showing the relation of current through the arc to potential difference of the electrodes or poles the *characteristic curve* of that arc, following a usual nomenclature in connection with dynamos. This characteristic is a curve sloping downward when the current is taken as abscissa and the P. D. as ordinate.

charged but charged up again in the opposite direction.[a] It parts with the excess of electrons forming the negative charge on its plate in connection with the negative arc terminal, and that plate is left with a deficiency of electrons, that is with a positive charge. Then the process repeats itself over again. Two conditions seem necessary for the automatic continuance of this process. First, the arc must be formed between terminals of such nature and in such surroundings that rapid variations of current through it must cause correspondingly rapid and large changes in the potential difference (P. D.) of the terminals in an inverse sense, that is, as H. T. Simon has shown, there must be a steep falling characteristic curve for the arc. (See fig. 10.)[b] Secondly, the arc must have the power of restarting itself if entirely extinguished for a short time, but this should not take place until the P. D. between the terminals exceeds a certain value, that is, it must not take place too easily or at too low a voltage. If the arc is formed between solid carbon terminals then it appears that these conditions are only fulfilled up to a certain frequency, that is when employing a rather large capacity in the condenser circuit. We then obtain Mr. Duddell's musical or singing arc, which emits a sound because the rapid variation of current through

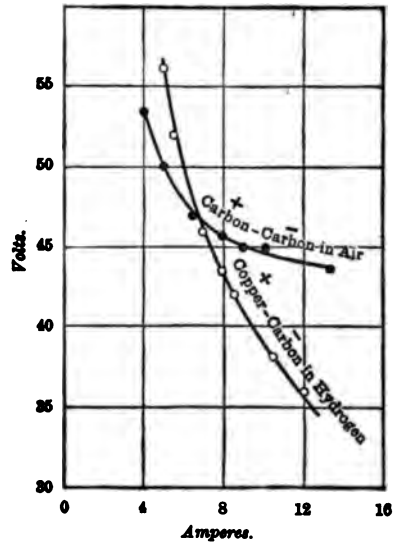


FIG. 10.—Characteristic curves for continuous-current arc in air and hydrogen (Upson). Arc length = 1.25 mm.

[a] The amplitude of the potential difference of the condenser terminals may and does become very much greater than the mere steady potential difference of the electrodes between which the arc is formed. Thus, with a P. D. of 220 or 300 volts across the arc the R. M. S. of the condenser plates may reach 1,000 or 1,500 volts.

[b] A careful study of the phenomena of the electric arc between metal and metal and carbon terminals in air and hydrogen has recently been made in my laboratory, under my direction, by Mr. W. L. Upson. It has been found that for an arc between a cold metal and a carbon terminal in hydrogen for the same length of arc, the rate of decrease of terminal voltage with increase of current is always greater than for an arc in air between two carbon terminals. In other words the volt-ampere characteristic is steeper. Also it has been found that in the case of a carbon arc in air the current can be interrupted for a much longer time without permanently extinguishing the arc than is the case for the metal-carbon arc in air or hydrogen.

the arc, by varying the energy expended in it, expand and contract the column of incandescent vapor forming the true arc, and therefore the layers of air next to the arc, and hence send out air waves which are heard as sound. Frequencies up to 10,000 or so are possible, although many physicists, such as Bannti, Corbino, and also Maisel, contend that much higher frequencies can be obtained. In 1903 Mr. Poulsen introduced a further improvement. He found that by inclosing the arc in a vessel containing hydrogen or coal gas, and forming the arc between a cold metal terminal, which is the positive, and a large carbon terminal, which is the negative, the arc being also traversed by a strong magnetic field, much higher oscillation frequencies could be obtained than with the double carbon arc in air. (See fig. 11.)

He also found it is an advantage to rotate the carbon terminal. When this arc is shunted by an appropriate small condenser in series

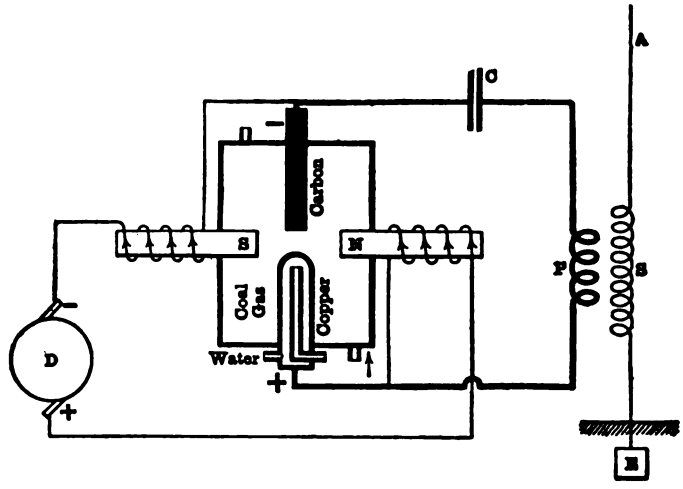


FIG. 11.—Poulsen's apparatus for creating undamped oscillations.

with an inductance, we can obtain in this last circuit electric oscillations having a frequency of a million or more depending on the capacity and inductance used. If a suitably tuned antenna is connected to one terminal of this condenser, and one arc terminal to the earth, as shown in the diagram, we are able to radiate from the antenna undamped trains of electric waves.

I have before me an apparatus of this kind with which much work has been done in my laboratory during the last few months. It consists of a water-jacketed brass cylinder with marble ends, through which project at one end a thick carbon rod, kept in rotation by a motor, and at the other a water-cooled brass tube with copper beak at the end. An electric arc is formed with 400–500 volts between the terminals taking 6–10 amperes.

The terminals are connected by a sliding inductance and by a condenser. Then, in addition, a long helix of wire is connected to one terminal of the condenser. This helix is tuned to the condenser circuit and may be taken to represent the antenna when the apparatus is used in wireless telegraphy. If we start the arc, then high-frequency oscillations are produced in the helix, and by the action of resonance the potential at the free ends becomes large enough to create an electric brush discharge. There is, of course, a strong oscillatory electric field outside the helix, and vacuum tubes held there, particularly neon tubes, glow brilliantly. It has been contended that these oscillations are undamped and continuous, but I can show you a simple experiment with a neon tube which proves that they are not always uninterrupted. If I hold a neon tube near the helix, and move it rapidly to and fro, you see a broad band of light, due to persistence of vision, but this is cut up by dark lines and spaces. In the same manner if a neon tube is rotated near the helix it does not produce a uniform disk of light, but the disk presents the appearance of radial dark bands and bright spaces. The same effect is seen with a vacuum tube filled with any other gas, provided the tube is sufficiently narrow in the bore. It appears to me that this proves incontestably that the oscillations are not uninterrupted, but are cut up irregularly into groups of various lengths.[a]

To obtain these high-frequency oscillations the various contributory factors—strength of magnetic field, length of arc, supply of coal gas—have to be carefully adjusted with reference to the capacity and inductance used and the voltage on the arc. No one who has practically worked with the apparatus can say that it is a simple and easy one to use. A very little want of exact adjustment causes the arc to be extinguished or else it fluctuates greatly in current, and compared with the extremely simple appliances required for spark telegraphy, the advantage in ease of working is largely on the side of the spark. But we have to consider whether there are not counterbalancing advantages as a generator of telegraphic electric waves which make up for the increased difficulty of working and greater complexity of apparatus. The claim made for it is that if the trans-

[a] Previous experimentalists seem to have been satisfied with examining in a revolving mirror the flaming arc or brush produced at the secondary terminals of a transformer, the primary of which forms the inductance in the condenser circuit, and finding the image drawn out into a band of light concluded that the oscillations were continuous. The neon tube is a more delicate test, and reveals the discontinuity mentioned above. This discontinuity of the train of oscillations seems to depend to some degree upon a want of perfect regularity in the rotation of the carbon terminal. It may also be brought about by the energy transferred to the condenser circuit being radiated or dissipated faster than it is supplied.

mitter produces undamped continuous oscillations these can be reduced to such small amplitude that they will not affect other neighboring wireless nonsyntonic receivers even if only a little out of tune, but can by the cumulative effects of resonance actuate their own corresponding or exactly syntonized receiver at the same or a greater distance. This claim is based on the known fact that for certain types of receiving circuit, the current created in them can be largely increased by increasing the number of oscillations in the incident train of waves, so that if oscillations or waves are undamped they can make up for feebleness by their persistency. This, however, depends essentially upon the nature of the receiving circuit, and is only true within certain limits.

When electric waves radiated from one antenna fall on another syntonized or tuned secondary circuit they set up oscillations in the latter of the same period. It might be thought that if these impinging waves are undamped, we should have an infinitely large current produced in the secondary circuit. As a matter of fact we do not. The electro-motive impulses from the sender only increase the secondary current up to a certain point. The secondary circuit necessarily possesses resistance and other sources of energy dissipation which rapidly increase with the current induced in it. Moreover, when the secondary circuit has an antenna attached, this itself radiates part of the energy it absorbs. Hence it follows that beyond a certain point the energy thrown onto the secondary circuit is no longer utilized to increase the current in it, but only just suffices to maintain it. The case is exactly analogous to that of a body being warmed by radiant heat. A thermometer exposed to full sunshine only rises to a certain height.

A comparison between the damped and undamped radiation, to be valid, must be made as follows: Assume that we have two wireless transmitting stations side by side, one sending out intermittent trains of feebly damped oscillations, the other continuous trains of undamped oscillations, and let them be so adjusted that the transmitters take the same mean power to work them. Let the frequency of these damped and undamped waves so radiated be the same. At a distance let there be a suitable movable receiving station, say a ship, with receiver tuned to the same frequency. Then the principal question at issue is, whether the undamped waves can affect this receiver at a greater distance than the damped waves of the same integral energy. Otherwise, at the same distance can the undamped wave station affect the receiver when using less power than the damped wave station. Since, however, by assumption the undamped waves from one station have the same integral energy as the damped waves from the other, the latter will have a higher initial value in each train to compensate for their decreased value and intermittent

cessation. Hence we may ask another question, viz, What will be their relative effect on receiving stations in their neighborhood not quite in tune with the emitted waves? Can we bring the undamped waves nearer into tune with these outlander stations without disturbing the latter, than we can in the case of the damped waves, and if so within what ratio of wave length? Claims have been made for a great superiority in this respect in the case of undamped waves, but we are still awaiting quantitative confirmation. Among other assertions it has been stated that the undamped waves are less easily "tapped," to use the newspaper expression. This is a fallacy. With the proper experimental appliances a receiving circuit can be gradually adjusted to any electrical frequency, and when it comes to the right frequency it must be affected just as much as true receiving stations for which the waves are intended. It is all a matter of apparatus and skill. To illustrate the first point, viz, the effect of the nature of the receiving circuit we may take an instance from optics. When we look through a telescope at the stars we can see a certain number down to some limiting magnitude. No amount of prolonged gazing when using the eye as a wave receiver increases the effect produced by a just invisible star. If, however, we use a photographic plate the effect on it is cumulative, and we can by a sufficiently long exposure obtain impressions of invisible stars in countless numbers. The photographic film is a wave detector of quite a different kind to the retina. In the case of the film it can make up by time what is wanting in intensity in the wave motion. In the case of wireless telegraphy it is clear, therefore, that the nature of the receiver has a great deal to do with the possible advantages of undamped waves, and it is not merely a question of the tuning or the transmitter.[a] Again, the ordinary 10-inch induction coil and spark transmitter as used on ships takes up one-fifth of a horsepower when in full work, and can send wireless messages 200 miles or more when an appropriate receiver is used. I find it very difficult if not impossible to obtain

[a] In order that he may take the utmost advantage of the principle of resonance, Mr. Poulsen uses in the receiver a device he calls a "ticker." This serves to keep the condenser-inductance circuit of the receiver closed, until resonance has exalted the oscillations to the utmost. The ticker then opens it at intervals and inserts the particular oscillation detector, whether electrolytic or other, which makes the audible or visible signal. In his syntonic receiver Mr. Marconi has always adopted a similar plan, for he keeps the coherer terminals joined by a condenser which closes the secondary circuit of the receiving jigger. A point of interest not yet considered is whether we *do* need absolutely undamped waves to gain all the possible practical advantages derivable from them. It may be that very slightly damped trains containing, say, 50 oscillations per train and following each other several hundred times per second will with an appropriate receiver give us all that we can obtain from the use of forced undamped waves.

sufficiently high frequency oscillations by the arc method unless at least 1 or 1½ horsepower is being expended in the arc. Hence, for short distance work on the point of economical working as well as simplicity of apparatus and ease of working the spark method has advantages denied to the arc. We were told not long ago by an eminent electrician that the arc method of creating undamped waves sounded the death knell of spark telegraphy. It is always advisable to exercise some caution in issuing obituary notices of well tried inventions prior to their actual decease, and in this case although the power to create continuous trains of electric waves will doubtless greatly assist space telegraphy, it does not follow that their generation by the arc method is the best or final method.

In the production of continuous oscillations we are not limited to the arc method. Mr. Marconi has for some time past been engaged in developing an ingenious method of creating undamped electric waves for telegraphic purposes which involves neither an arc nor alternator, but is a new mechanical method of great simplicity.

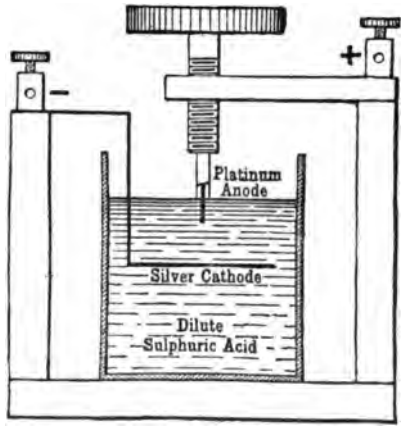


FIG. 12.—Electrolytic detector.

This method is capable of producing astonishingly large alternating currents of very high frequency, in other words, so called undamped or persistent oscillations. I have recently witnessed some of his experiments, and was surprised at the results obtained. Long distances have been telegraphically covered with every prospect of great efficiency. Unfortunately, the incomplete state of certain foreign patents prevents me from entering into details of this method now, but I hope he himself will be able to do so soon.

Turning then from transmitters to receivers, we may notice one or two recent types. By far the larger portion of electric wave telegraphy was until a few years ago conducted by means of some form of coherer, either requiring tapping or else self-restoring. The coherer in certain forms has the advantage that a current of about 0.1 to 1.0 milliampere can be passed through it, and hence through a relay, so that messages can be printed down by it when using a Morse inker in dot and dash signals. After that came Mr. Marconi's magnetic detector, making use of a telephone to create an audible signal. This is now the instrument employed by him on all long distance work. In Germany and the United States a type of telegraphic wave detector has come into use, commonly called the electrolytic receiver. In one form it was invented

in the United States by Fessenden, and called by him a liquid barretter. It was independently discovered, and described shortly afterwards in Germany by W. Schloemilch, and is generally there called the electrolytic detector. (See fig. 12.) It consists of an electrolytic cell or vessel containing some electrolyte, usually nitric acid. In it are placed two electrodes, one a metal or carbon plate of large surface, and the other an extremely fine platinum wire prepared by the Wollaston process, a very short length of which is immersed in the liquid. A convenient plan is to prepare a Wollaston wire of silver, having a core of platinum which is drawn down until the latter is only one one-thousandth of a millimeter in diameter. If the electrolyte is strong nitric acid, then when the above wire is immersed to the depth of a millimeter the acid dissolves off the silver and leaves the fine platinum wire exposed as an electrode. This cell has its two electrodes connected respectively to a receiving antenna, and an earth plate, and also to a circuit containing a shunted voltaic cell and a telephone. (See fig. 12A.) The voltaic cell sends a current through the electrolyte in such a direction as to make the fine wire the positive electrode or anode. Some dispute has taken place whether the cell will work when the fine wire is the negative electrode. Fessenden, who adopts a thermal theory of the cell, claims with Rothmund and Lessing that it is equally sensitive, whether the small electrode is positive or negative.

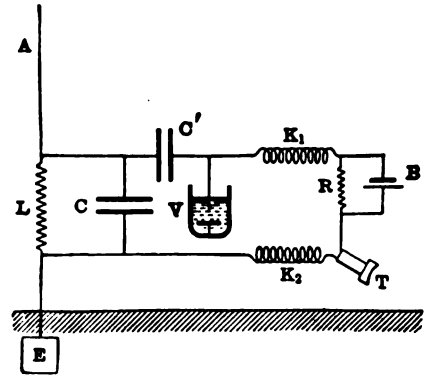


FIG 12A.—Electrolytic detector with shunted cell and telephone.

According to one theory, the action of the cell as a wave detector depends on the power of the oscillations to remove the so-called polarization of the electrodes or adhering films of ions. According to another theory it is due to the heating action of the oscillations on the small electrode and liquid in its neighborhood. In any case, the action is just as if the resistance of the electrolytic cell were suddenly changed, either increased or decreased. It has also been found by Rothmund and Lessing that the cell may be made to supply its own electromotive force. If we form a simple polarizable voltaic cell with fine zinc and platinum wires immersed in dilute acid and connect a telephone or high resistance galvanometer to these elements; then, when electric oscillations pass through the cell, the current sent by it through the telephone or galvanometer is momentarily increased.

That the action is not altogether due to the removal of polarization films is shown by the fact that the fine platinum wire in the Schloemilch form of detector wears away or is dissolved in the nitric acid when oscillations are passed for some time through the cell, and there is some evidence that gold and platinum can be made to dissolve even in dilute acids by the action of electric oscillations.

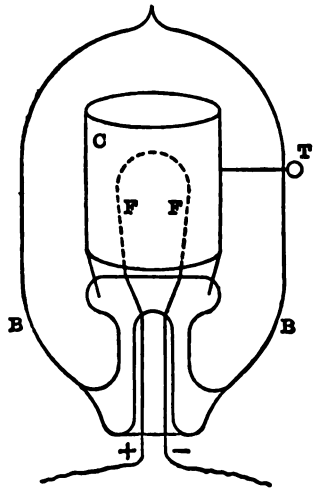


FIG. 13.—Oscillation valve (Fleming).

In 1904 I was so fortunate as to discover another and quite different principle on which a sensitive electric wave detector can be based. If a carbon filament glow lamp has a metal plate carried on a third terminal sealed into the bulb, it is well known that a current of negative electricity flows from the plate to the positive terminal of the lamp, when the filament is rendered incandescent by a continuous current. This is the so-called Edison effect. It is also now known that incandescent bodies discharge negative corpuscles or electrons from their surface, and incandescent carbon, when in a vacuum, exhibits this power in a marked degree. Negative electricity escapes freely from it, but not positive. In 1904 I was endeavoring to find some way of rectifying electric oscillations, that is, of separating out the two sets of alternate currents and making them separately detectable by an ordinary galvanometer. It occurred to me to make use of a carbon filament lamp, having a metal cylinder insulated in the bulb surrounding the filament, the cylinder being connected to a platinum wire sealed through the bulb. (See fig. 13.) This lamp was then used as follows: A circuit was connected between the terminal of the metal plate and the negative terminal of the filament, the latter being made

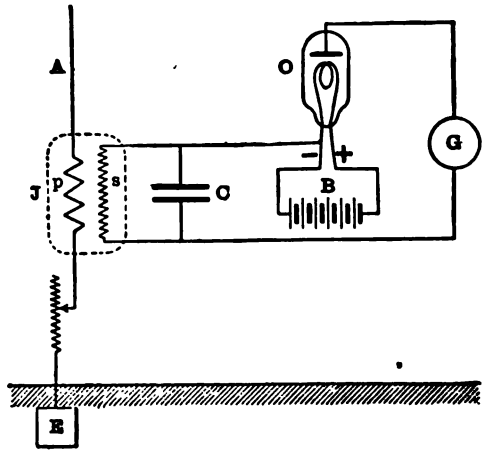


FIG. 14.—Oscillation valve or glow lamp detector, used as a receiver in electric wave telegraphy.

brightly incandescent by a small battery. In this circuit a galvanometer and one circuit of a small transformer or induction coil was inserted. On connecting the other circuit of the transformer between an antenna and the earth, I found that the oscillations set up in the antenna caused a deflection in the ordinary mirror-galvanometer. (See fig. 14.) The action is as follows: The antenna oscillations induce others in the circuit of the transformer, which is in connection with the lamp. A movement of electricity in this circuit, which consists in the flow of negative electricity from the filament to the plate through the vacuum, can take place, since this negative electricity is, so to speak, carried across the vacuous space by the electrons emitted from the hot carbon. On the other hand, negative electricity can not flow in the opposite direction. Hence the glow lamp separates out the two oppositely directed movements of electricity and allows only one to pass. I therefore called the appliance an oscillation valve. This instrument was shown by me to the Royal Society early in February, 1905, and was employed by Mr. Marconi soon after as a long-distance wireless-telegraph receiver, in conjunction with other improvements. M. Tissot, of the Naval College, Brest, in France, has made use of this glow-lamp detector, and with a sensitive galvanometer has received signals at a distance of 50 kilometers.[a] Employing a special form of transformer, and a telephone in place of a galvanometer, Mr. Marconi has used it for some time past over distances of 200 miles or more, and finds it a very sensitive form of receiver. Since this particular form of electric wave detector was brought to notice by me, Doctor Wehnelt has found that a metallic wire, coated with oxides of calcium, barium, or other earthy metals, may be substituted for the carbon filament in the vacuous bulb.

The oscillation valve is capable of giving very remarkable effects when used as a receiver with a transmitter producing undamped waves. The reason for this is obvious. The valve passes all the unidirectional currents in the attached secondary circuit. If, then, these are intermittent damped trains, say having a frequency of 100,000, and 50 trains of 20 oscillations per second, the total time during which electric current is passing is only one-thousandth of the whole time. Accordingly, if we, so to speak, fill up the gaps between the trains of oscillations with other oscillations, and generate a continuous train, we greatly increase the quantity of electricity passing and repassing any point in the secondary circuit, and the indications on a galvanometer in circuit with the valve are enormously increased. A true comparison between the two cases of

[a] See The Electrician, Vol. LVIII, p. 730, Feb. 22, 1907. M. C. Tissot, "On Ionised Gas Electric Wave Detectors."

damped and undamped waves involves many factors, and is not fair unless we compare together transmitters taking the same mean power. Generally speaking, however, we may say that not only this glow-lamp detector, but all forms of thermal detector, give greatly increased effects when employing undamped oscillations. I find, for instance, that if undamped oscillations are created in a closed wire circuit which forms part of a circuit containing capacity and inductance shunted across a Poulsen arc, I can induce powerful secondary oscillations in a similar closed and syntonic secondary circuit at a considerable distance, and detect these by the use of my oscillation valve and a galvanometer placed. In fact, the use of undamped oscillations in a closed primary circuit, and this oscillation valve used with a telephone in a closed secondary circuit, brings to the front again the possibility of making use of so-called wireless telegraphy by electro-magnetic induction over very large distances. The old form of electro-magnetic induction telegraphy as practiced by Trowbridge, Preece, Lodge, and others made use of low-frequency alternating currents (50 to 100) in a closed primary circuit, and employed a telephone in a distant closed secondary circuit to detect the magnetic field so produced, signals being made by interrupting the primary current. I have, however, found a means of greatly improving this form of wireless telegraphy. In a closed primary circuit I establish continuous undamped oscillations of, say, a quarter of a million frequency by the arc method. At a distance I place a syntonic secondary circuit containing my oscillation valve as a detector, a telephone being used with it connected between the middle plate and negative filament terminal. Both the primary circuit and secondary circuit are connected to earth at some point. The signals are made by breaking and making the earth connection of the transmitter in accordance with Morse code. When the earth connection is made at both ends a sound is heard in the telephone, but not when it is broken. This seems to depend upon the fact that the oscillations produced by the arc method are not absolutely continuous, but cut up into groups, as already proved by the experiment with the rapidly moving neon tube and helix.

I have found that it is not necessary to employ a high-voltage carbon filament, a small lamp with 4-volt filament, taking about one ampere, works quite as well as a wireless telegraph receiver as a 12 or 100 volt lamp. The filament has, however, to be at a certain critical temperature to obtain the best result; the vacuum also has to be extremely good. There are, no doubt, many possible variations of the above-mentioned type of oscillation valve wave detector. Every glass vessel containing rarefied gases or mercury vapor having electrodes of different sizes or shapes or temperatures, has some degree of unilateral conductivity, and can be used in the above manner

to separate out the two constituent currents of an electrical oscillation, and make them detectable by an ordinary galvanometer or telephone. I have also tried with some success a flame in which two platinum wires are immersed, one of which carries a bead of potassium sulphate as a means of rectifying oscillations of high frequency. It is well known that negative ions are then liberated in the flame, and negative electricity can pass over more freely from the electrode which carries the bead of salt to the other than in the opposite direction. I have not, however, found anything as simple and useful as the above-described low-voltage carbon filament glow lamp. Moreover, other inventors have indorsed its utility by granting it the compliment of imitation. In October, 1906, Doctor de Forest described to the American Institute of Electrical Engineers an appliance he called an "audion," which is merely a replica of my oscillation valve, described to the Royal Society eighteen months previously and to the Physical Society of London six months before, particularly with reference to its use as a wireless telegraph receiver. Apart from the name the only difference introduced by him was to substitute a telephone and battery in series connected between the middle plate and positive terminal of the filament, for the galvanometer used by me connected between the middle plate and the negative terminal. As Mr. Marconi had before that time used my oscillation valve with a telephone with it for long distance work, and M. Tissot has found a galvanometer, used as I described it, effective up to 50 kilometers, the modification made by Doctor de Forest does not make any fundamental difference in the operation of the device as a wave detector.[a]

Very closely connected with the question of the production of continuous or undamped electric waves is that of the electrical transmission of speech through space without wires; in other words, wireless telephony. Some considerable progress has already been made in this direction. Any complete treatment would require a lecture in itself. If, however, we pass by the investigations of Bell with the photophone, Simon, Ruhmer, and others with apparatus employing the resistance variation of selenium by projected beams of powerful light, and also those of Preece, Gavey, and others with electro-magnetic induction, we may say that at the present time the chief interest attaches to methods of wireless telephony which involve the use of undamped electric waves. The problem may then be stated to be as follows: Articulate speech made against a diaphragm at a transmitting station has to affect similarly the diaphragm of a telephone at a receiving station not connected with it by wire.

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[a] In a private letter M. C. Tissot has already acknowledged gracefully my priority of invention in this matter, although he himself was independently working in the same direction.

Time only permits me to give you a brief sketch of some interesting experiments which have been carried out lately by the German Wireless Telegraph Company between Berlin and their large station at Nauen, 20 miles distant. At the transmitting station they employ 12 electric arcs in series, each of which is composed of a carbon negative and a water-cooled copper positive electrode. These arcs take 4 amperes at 440 volts. (See fig. 14.) In parallel with this series of arcs is joined a condenser and inductance, to which is inductively but loosely coupled an antenna from which undamped electric waves, 800 meters in wave length, are radiated, having a frequency, therefore, of 400,000. The oscillations set up in this antenna can be more or less enfeebled by shunting them to earth through a microphone transmitter, the resistance of which is varied by the act of speaking against it. Hence, although the wave length of the emitted electric waves is not altered, their intensity is modulated in accordance with the wave

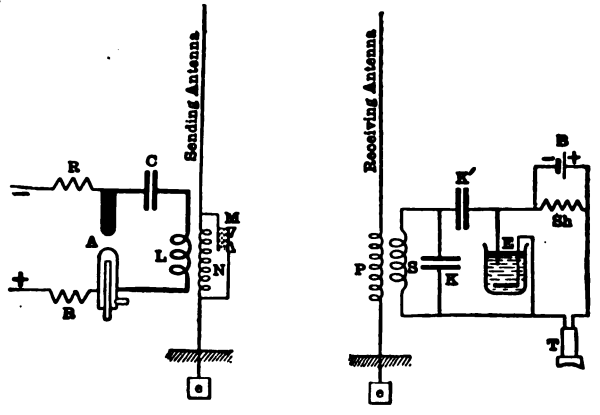


FIG. 15.—Wireless telephony by electric waves.

form of the sounds impressed on the transmitter diaphragm. At the receiving station there is a receiving antenna tuned to the wave length used, having a quantitative electrolytic detector in connection with a telephone coupled inductively to the antenna circuit. Hence the vibrations of the transmitter diaphragm vary the intensity of the radiated electric waves but not their wave length. These waves travel through space, fall on the receiving antenna and affect the resistance of the electrolytic detector in proportion to their intensity. Hence the receiving telephone repeats the sounds or articulations made against the transmitting microphone and reproduces speech. The German experimentalists say that a satisfactory wireless transmission of speech can be made in this manner, 20 kilometers or 12 miles over water with antennæ 25 meters or about 80 feet high.

Ruhmer has recently described in the Elektrotechnische Zeitschrift some similar experiments made with a 220-volt Poulsen arc. In this

case the necessary modulation was impressed upon the radiated electric waves by inserting the primary circuit of an induction coil in the continuous current arc circuit, and closing its secondary through a microphone transmitter and working battery. The receiving arrangement involved an electrolytic receiver as just described. Professor Fessenden has recently described very similar arrangements for electric wave wireless telephony.[a] We can, however, say that something more than a beginning has been made in the art of the wireless transmission of human speech to a distance. The energy expenditure is at present considerable, and much will have to be done before telephony without wires can be looked upon as coming within the range of commercial work. Nevertheless, having regard to the enormous improvements in wireless telegraphy in the last seven years, it is quite within the bounds of possibility we may soon be able to speak across the English Channel without a wire, and not scientifically impossible for the sounds of the human voice to be some day transmitted from the shores of England or the United States to an Atlantic liner in mid-ocean.

We may consider in the next place another problem of great practical importance, toward the solution of which some considerable progress has been made, viz, that of locating the direction of the sending station and giving direction to the emitted radiation sent out from it. The early attempts to do this depended upon the use of parabolic mirrors, or some arrangement of vertical rods equivalent to it. But although comparatively short electric waves of a few feet in wave length can be directed in this manner in the form of a beam, it is out of the question for electric waves hundreds of feet in length, because reflection can only take place when the dimensions of the mirror are at least comparable with that of the wave length.

The ordinary vertical antenna, of course, radiates equally in all directions, and when it is so far off as to be below the horizon a corresponding receiving antenna may respond to it, but can not locate the position of the sending station.

It seems to have been noticed by several persons that if the antenna is not vertical, it radiates rather more in one direction than another, and the same for a nonvertical receiving antenna. It is more receptive to waves coming from one direction than another. Various observations on the operation of nonvertical, looped, or duplex antennæ have from time to time been made by Zenneck, Sigsfeld, Strecker, Slaby, and De Forest, whilst methods for locating the sending station or directing the transmitted waves were described in patent specifications by De Forest, Garcia, and Stone. Although claims were made for arrangements said to be effective, these various

[a] See The Electrician, Vol. LVIII, p. 710, 1907.

researches were not pressed to such logical issue as to disclose any definite general scientific principle, whilst in some cases the results said to have been obtained are clearly in contradiction to well ascertained facts.

Time will not permit further reference to these early and inconclusive observations.

In March last year Mr. Marconi communicated to the Royal S[illegible] a paper on the r[illegible] from an antenna [illegible] a short part of its [illegible] vertical and the [illegible] part horizontal. the receptive po[illegible] similar antenna [illegible] ous azimuths.

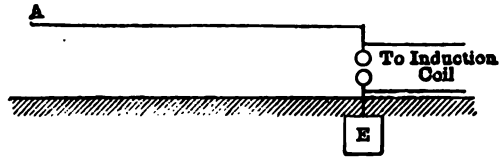
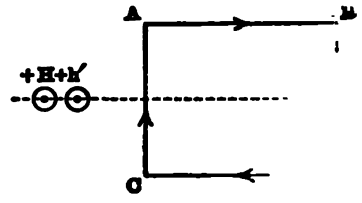


FIG. 16.—Marconi bent antenna.

16.) He found that such a bent antenna emits a less intens[illegible] at any given distance in the direction in which the free end [illegible] in the opposite direction. Also, since the law of exchange for electric radiators, a similar form of antenna receiv[illegible] best electric waves which reach it from a direction o[illegible] to which the free end points.[a] Hence two similar bent [illegible] set up back to back, that is, with their free ends poin[illegible] each other, form a system of radiator and receiver which has greater range in that position than in any other for the same distance, and hence has directive qualities not possessed by the ordinary vertical antennæ.



Although I have given the mathematical explanation of the reasons for this in another place,[b] it is not difficult to translate the common sense of it into nonsymbolic language. Imagine a square circuit of

FIG. 17.—[illegible]

[a] This is an extension to electric radiat[illegible] Theory of Exchanges, as amplified by [illegible] forms the basis of spectrum anal[illegible] and others.

[b] See "A [illegible] Vol. LX[illegible]

the earth. (See fig. 17.) Let a current be supposed to flow round it, in clockwise direction. Then it creates a magnetic field, the direction of which along the surface of the earth in a direction at right angles to the plane of the circuit, and at equal distances from the center, is toward the spectator on both sides. Suppose, then, that a wire equal in length to one side of the square is placed in contiguity to one vertical side, and that it carries a current opposite in direction to that in the side of the square (say, the right-hand side) to which it is in proximity. Then the magnetic field of this straight current is from the spectator at the right-hand side and to the spectator on the left-hand side. Accordingly, the total field on the right-hand side, due to the currents in the closed and open circuits together, is less than that on the left, because the individual fields are added on one side and subtracted on the other. Since the two oppositely directed currents in the adjacent wires may be imagined to come so close as to annul each other, and since the parts of the remainder below ground may be considered to be removed without affecting the field above ground, we arrive at the conclusion that an antenna partly vertical and partly horizontal radiates most strongly in the direction opposite to that in which the free end points.

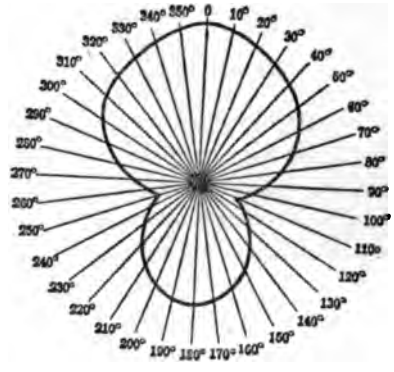


FIG. 18.—Radiation in various azimuths from Marconi bent antenna.

Mr. Marconi discovered this fact experimentally, and made measurements of the currents induced in receiving antenna placed at equal distances round this bent transmitter, and plotted the results in the form of a polar curve. (See fig. 18.) As a quantitative receiving detector he made use of a Duddell's thermal ammeter. In repeating and confirming these experiments on a smaller scale last summer in the grass quadrangle of University College, I employed a form of thermal ammeter of my own design, made as follows: A vacuum vessel made like those which Sir James Dewar devised for storing liquid gases has four platinum wires sealed through the bottom of the inner test tube. One pair of these is connected in the vacuous space by an extremely fine constantin wire and the other pair by a fine tellurium-bismuth thermo-junction, with the junction resting on the fine wire. (See fig. 19.) When a galvanometer of suitable resistance is connected to the terminals of the thermo-junction and the constantin wire inserted in the circuit of the receiving antenna we have an arrangement which enables us to measure as well as detect the intensity of the electric waves incident on the antenna. This detector,

skillfully made by my assistant, Mr. Dyke, proved very useful. I was thus able to confirm Mr. Marconi's observations and my own theory of them, and furthermore noticed that when the nonvertical part of the transmitting antenna was bent so that it was not horizontal but pointed downwards, a very remarkable nonsymmetry of radiation occurred, quite, however, accounted for by theory. (See fig. 20.) Mr. Marconi has made very effective practical use of the bent receiving antenna to locate the position of a ship or station sending out electric-wave messages when so far off as to be below the horizon.

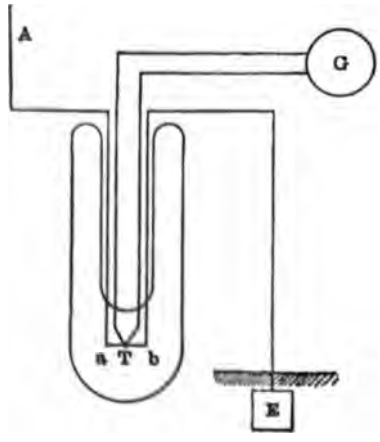


FIG. 19.—Thermal detector.

In this case he arranges the receiving antenna so that a very short part is vertical and the greater part horizontal, and furthermore permits the horizontal part to be swiveled round the vertical part as a center. In the vertical portion he places his magnetic or some other detector. If, then, there be a distant station in correspondence with this receiver, the direction in which the transmitter lies can be determined within a few degrees by swiveling round the receiving antenna and noting the position in which it picks up signals or picks them up best from this transmitter. The transmitter then lies in the direction opposite to that in which the free end of the receiver wire points. If it is not convenient to swivel round the horizontal portion, then Marconi arranges a number of horizontal receiving antennæ like the spokes of a wheel, all having a common

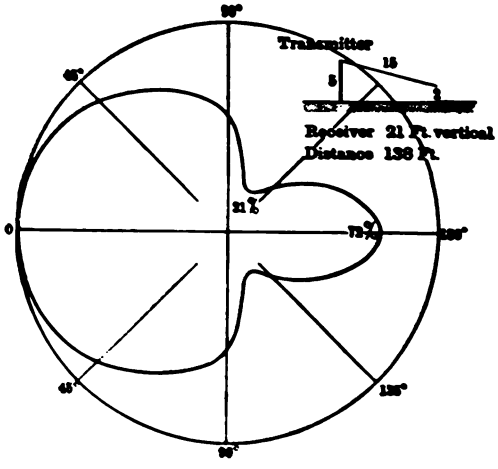


FIG. 20.

rter vertical part as their center. (See fig. 21.) In the vertical rt a magnetic detector is inserted, and by means of a switch any one horizontal radial antennæ can be put in connection with it. By which radial gives the strongest signals, the direction of the

sending station is easily located. It will be seen, therefore, that two well-defined principles had been arrived at by Marconi. First, that the nonsymmetry of the radiation and reception depends upon the employment of antennæ having their horizontal portions large compared with the vertical, and secondly, that the maximum radiation is in the direction opposite to that in which the free end of the horizontal part points. These observed effects rest on a sound scientific basis, and, as I have shown, are immediately derivable from first principles.

Previously to Marconi's experiments no definite guiding principles as to directive telegraphy had been published, but a number of unconnected observations made, not always correctly interpreted or even described, and in any case with limited application.

Meanwhile, however, Prof. F. Braun, of Strassburg, had been engaged on a different plan for directing the radiation from antenna. Briefly stated, his method is as follows: He erects three vertical antennæ at the corners of an equilateral triangle, or four at the corners of a square, the sides of which are about equal to the height of the antennæ, and he creates in them electrical oscillations which have a defined and constant difference of phase by methods contrived by him, Doctors Papalini and Mandelstam, not yet fully described. It is found that the waves sent off from these three antennæ interfere with each other in an optical sense, exalting each other in some directions and nullifying each other in other directions, in accordance with their relative amplitude and phase difference. The resultant effect can be so arranged that the radiation is extremely unsymmetrical, being much more toward one side than the other. The intensity in various azimuths may be represented by the *radii vectores* of a sort of oval or heart-shaped curve, the triple transmitter occupying a position on the cusp or apex of the curve. (See fig. 22.) It will be seen, therefore, that popular notions on the subject of directive telegraphy are wide of the mark. Whilst we can not yet project a narrow beam of long-wave electric radiation in any required direction, or focus it entirely on a given receiving station at a great distance, much can be done to prevent radiation being sent out from transmitters in directions in which it is of no use or not desired.

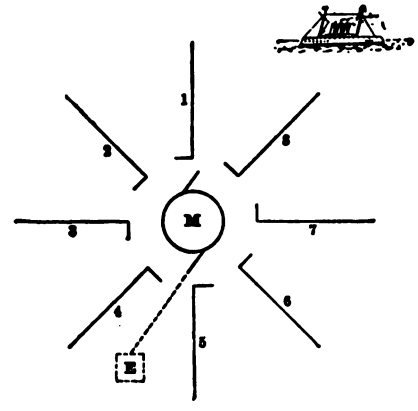


FIG. 21.—Marconi localizing antenna.

At coast stations communicating with ships at sea something has already been done to achieve this result. Mr. Marconi has for some

time past employed such directive antennæ at his large power stations at Poldhu and elsewhere.

These, then, are a few of the contributions which have recently been made by practicians and theorists to this fascinating and progressive subject. But whilst we may congratulate ourselves that progress continues to be made, there are still large districts of it in which our knowledge is most incomplete. One matter having a very practical bearing is the necessity for systematic study of the causes which vary the transparency of space to long electric waves. You will continually see references in the daily papers to isolated feats of communication between ship and ship, or ship and shore, over unusually large distances. Ships equipped with what is called short-distance apparatus, that is intended to send and receive over 200 miles or so, are able occasionally to communicate with others 600, 800, or even 1,000 miles away. This is not altogether a matter of personal skill or of apparatus. Our terrestrial atmosphere varies from day to day and hour to hour in its transparency to long telegraphic electric waves, just as it does to the short light waves. One reason, and probably a valid one, which has been advanced for this is the ionization of the atmosphere by sunlight, radio-active matter, or matter electrically charged reaching our earth from the sun or cosmical space. These ions or electrically charged particles suspended in the air are set in motion by the electric force of long electric waves passing through the region. This, however, involves energy which must be taken from the wave, and hence the wave passes on so much the weaker. This effect is altogether different from the disturbing effects of atmospheric electricity on the receiving antenna. As first noticed by Mr. Marconi on one of his Atlantic voyages, the atmospheric transparency for long electric waves is decreased by daylight and this reducing effect of light on the wave energy takes place chiefly near the transmitting antenna where the electric force is largest. It fluctuates from hour to hour and month to month according to laws as yet undetermined, and has no doubt secular and irregular fluctuations superposed on its regular variations. The subject of long-distance wireless telegraphy is yet too young to provide observations for any

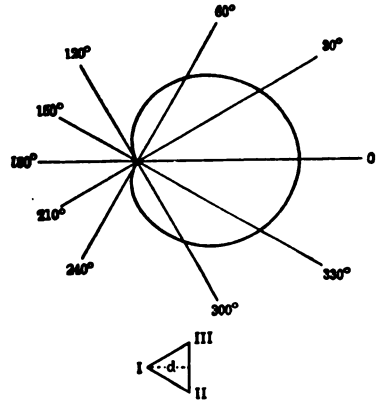


FIG. 22.—Polar diagram for Braun's triple directive antenna.

safe generalizations on this matter, but doubtless these will be accumulated in course of time.

Wireless telegraphy has now reached a position of such importance, especially in connection with supermarine communication, that scientific research for its advancement should have the utmost possible encouragement, subject, of course, to the consideration that there is only one ether for us all. Whilst we derive satisfaction from the thought that so much valuable discovery and invention has already rewarded the labors of workers in many lands, we have but to glance around us to see in all directions, in connection with it, unsolved problems, untrodden paths, wide fields of knowledge ripe for harvest in which the sickle of the reaper has never yet been moved.

ON THE PROPERTIES AND NATURES OF VARIOUS ELECTRIC RADIATIONS.[a]

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We are now aware of the existence of a number of different types of radiation, each of which is able to ionize a gas, to act on a photographic plate, and to excite phosphorescence in certain materials. Of these the α and canal rays consist of positively charged particles of atomic magnitude; the cathode and β rays are negative rays, and consist of electrons; the X and γ rays are supposed to be ether pulses; and ultra-violet light consists of short ether waves. The δ rays stand by themselves, for, though they consist of negative electrons like the cathode and β rays, they have so small a velocity that they possess no appreciable ionizing powers.

The present paper contains, in the first place, an attempt to find whether there is anything to be learned from a comparison of the properties of the various rays; and, in the second place, a discussion of the possibility that the γ and X rays may be of a material nature.

It appears to me to be a first deduction from such a comparison that in all cases the bulk of the ionization which the rays effect is of the same character, and consists in the displacement of slow-moving electrons, or δ rays, from the atoms of the gas or other substance which they traverse. Let us consider the various rays in turn.

In the case of the cathode rays this principle has been clearly established by Lenard in the course of his long series of beautiful experiments. He has shown that cathode rays of the most varied speeds, impinging on bodies of various kinds, or traversing different gases, cause the liberation of slow-speed electrons from the atoms of the solid or gas. The speed of the electrons is in every case that due to the fall through less than ten volts. This is in no way a contradiction of the fact that cathode rays of high speed are also liberated from a solid surface struck by primary cathode rays; or from atoms

[a] Read before the Royal Society of South Australia in two parts: the first on May 7, 1907, the second on June 4, 1907. Reprinted, by permission, from the Philosophical Magazine for October, 1907.

of a gas through which the primary rays pass. But, whether these high-speed secondary rays are scattered primary rays, or are true secondary rays, they must in their turn produce electrons of slow speed in the gas through which they pass; and so, directly or indirectly, by primary or secondary or tertiary or rays still more transformed, eventually the great majority of the electrons set free in the ionization chamber of ordinary experiment are of the slow-speed type.

In the case of the α rays there is abundant evidence that their impact on, or emergence from, solid surfaces causes the ejection of slow-speed electrons. (J. J. Thomson, Cambridge Phil. Soc. Trans., February, 1905; Rutherford, "Nature," March 2, 1905; Logeman, Proc. Roy. Soc., September, 1906.) Now, it is generally characteristic of all these electric radiations that they are concerned with the individual atoms and molecules, and that they do not recognize any difference between the atom in the solid and the atom in the gaseous condition. Consequently, there is every reason to suppose that the heavy ionization caused by an α particle in traversing a gas consists in the production of the same slow-speed electrons as are set free from a solid, and indeed no trace of faster-moving electrons has ever been found. The slow-speed electrons originated by α rays have been called δ rays, and the term may be applied to all such slow-speed electrons as we are now considering.

Again, it has been shown by Fuchtbauer (Phys. Zeit., November 1, 1906) that δ rays are emitted from a metal surface struck by canal rays; and here also there is every reason to suppose that gas molecules struck by such rays emit the same δ particles. The same author has shown by a direct comparison that the velocity of these particles is the same as that of the δ rays displaced by cathode rays, i. e., about 3.3×10^8 cm./sec., or the velocity due to about 20 volts, a velocity only slightly larger than that found by Lenard.

As regards β and γ rays, it is true that is has not been definitely proved that most of the ionization which they cause is of the δ type. But this may be inferred from well-known experiments, such as those of Durack (Phil. Mag., May, 1903), or McClelland (Trans. Roy. Dub. Soc., February, 1906). When a pencil of β radiation is allowed to cross an ionization chamber normally, and fall upon the opposite wall, it gives rise to a secondary ionization, less in quantity, but not much less in speed than the primary. A tertiary radiation is caused by the secondary rays if they impinge on the walls of the chamber, and there will doubtless be still further derivations. But it appears that the quantity of the derived radiations dies away much more quickly than the speed. Thus the chamber is crossed and recrossed (a few times) by electrons of high speed, able to traverse an average path of about 100 cm. in air at atmospheric pres-

sure. If the chamber is first exhausted and air gradually admitted, it is found that the number of ions produced by the β rays is proportional to the pressure. The paths of the β rays will not be appreciably affected by the introduction of the air; and so the experimental results are consistent with the simple hypothesis that the β particle (primary or secondary) makes slow-speed ions in proportion to the number of gas atoms traversed. Nor does any other hypothesis seem to be consistent with the facts. It can not be supposed that the bulk of the ionization which is caused in the ionization chamber consists of high-speed secondary rays, though, of course, these are originated when the primary rays strike the metal surface of the chamber, and to a small extent when they strike gas molecules. For if all the negative electrons set free by the β rays were of high velocity we should expect certain effects, as may be seen from the following considerations, and none of these effects have been observed.

Rutherford has shown ("Radioactivity," 2d edition, p. 434) that the α particle of Ra makes about 86,000 ions in air; that one β particle is emitted from Ra for every four α particles; and that the ionization due to β particles is of the order of 1 per cent of that due to α particles in the case of Ra in equilibrium. Thus the β particle of Ra produces some thousands of ions. This is also evident from the experiments of Durack (Phil. Mag., May, 1903), who has shown that the β particle produces about 130 ions per cm. in air at atmospheric pressure. Now, the β particle runs a course in the open air of an average length of 100 cm. This leads to an estimate of its ionization even greater than that obtained by Rutherford. If all the electrons, so liberated, had a high velocity, the energy set free would be out of all proportion to that of the original β particle. Yet if we are to ascribe a high velocity to the electrons set free, it must be a very high one, for it has been shown by Allen (Phys. Review, August, 1906), that the secondary radiation of β rays consists of electrons moving with a speed approximating to that of the primary. We can not suppose that all these electrons are of this high-speed type. Moreover, if this were the case, the free path of such electrons would become comparable with the dimensions of the ionization chamber, when the air pressure was only moderately reduced, and the electrons would then be beyond the control of the electric field. Thus the ionization would not be proportional to the air pressure, as was found by Durack and McClelland. The difficulty as to the energy is not obviated by supposing each primary β particle to set free only a few secondary electrons of high speed, each of these to become in turn the originator of a few more, and so on. For if that were the case, a reduction of gas pressure would imply, not only

that each primary electron set free fewer secondary electrons, but that each of the latter set free fewer tertiaries, and so on, so that the ionization would fall at a far greater rate than the pressure as soon as the free path of the electrons became comparable with the dimensions of the chamber. And, again, the β rays differ only in speed from cathode rays, which produce quantities of slow-speed electrons, even where their own velocity is great.

For these reasons I think it must be concluded that the β particle (and any high-speed secondary) produces slow-speed electrons along its path, in very much the same way as the α particle does, though not in such great numbers. The high-speed secondary rays, studied by McClelland, Allen, and others, are but few in number compared to the slow-speed electrons, though their greater energy puts them more in evidence. McClelland concludes from his experiment that the β rays do not produce any slow-speed electrons, when they strike a metal surface, which are comparable in number with the electrons displaced in the gas through which they have passed. This is quite consistent with what has been said above. There must be a few, but the number to be expected is quite small, for the β electrons dive so deep into the metal which they strike, and ionize so few of the molecules through which they pass, that very few of the slow-speed, highly absorbable electrons can be discharged from the surface of the plate. Even in the case of the α particle these electrons are not readily observed; in the case of the β particle the difficulty must be much greater.

As regards X rays, we have no such accurate measurements of the velocities of the electrons which are ejected from the molecules of a gas traversed by the rays, as we have in the case of the cathode rays, so far as I am aware. But a very large amount of labor has been spent on the investigation of the secondary radiation caused by the X rays, from which we may gather much indirect evidence on the point. Perrin (Ann. Chim. Phys., XI, p. 496, 1897) has shown that the rate of production of ions per cc. by rays of given intensity is proportional to the pressure of the gas. Again, we know from the investigations of Curie and Sagnac, Townsend and Barkla that metals struck by X rays return a secondary radiation, which, in the case of the low atomic weights, may be considered to consist principally of scattered primary radiation, and in the case of the high atomic weights to contain both X rays more absorbable than the primary and cathode rays. Dorn has shown that the latter have speeds averaging about 5×10^9 cm., so that they must produce considerable ionization, consisting of δ rays, in the few millimeters of air close to the metal. The free path of electrons having this speed is about one millimeter in air at atmospheric pressure. Since the X rays do not

appear to produce cathode rays of any speed from the air molecules which they traverse, or from the molecules of any gas consisting of atoms of small weight, and since they produce much ionization in some way or other, we may conclude fairly that they produce slow-speed ions themselves. Thus, whether they act directly or indirectly through cathode rays, the result is the same. The principal effect appears to be due rather to secondary than primary. As Sagnac remarks (Ann. Chim. Phys., XXIII, p. 196), "The transformation of X rays, by increasing the activity at any point, permits the detection there of very penetrating X rays, which would otherwise have passed unperceived."

In the case of the γ rays, such evidence as we have is also in favor of the existence of slow-speed ions, as the result of their action. It is known that β rays of high speed originate where they strike the molecules of a solid body (Eve, Phil. Mag., December, 1904); such an action may, therefore, be expected in the case of gas molecules also. It is possible, however, that there may be a differential effect in respect to heavy and light atoms, as in the case of the X rays. The β rays will produce δ rays in their turn; and if, as is probably the case, the γ rays are themselves able to ionize, the product will consist of δ rays, a conclusion which may be safely adopted from the analogies of the cathode rays on the one hand and the X rays and ultra-violet light on the other. As in the case of the hard X rays, the existence of γ rays is often made clear by the secondary effects which they produce, as has been shown by Becquerel.

To sum up what has been said, the ionization which we measure in the ionization chamber is almost wholly due to the emission of slow-speed electrons from the atoms of the gas contained in the chamber or of the chamber walls; and this is true for all forms of radiation.

Moreover, there is some evidence to show that the speed of the δ rays is almost independent of the cause and manner of their production. As has already been said, Fuchtbauer found the velocity of the δ rays, caused by canal rays, to be about $3\ 3\times10^8$, and the same in the case of cathode rays. Logeman found the velocity of the δ rays, emitted from a plate struck by α rays, to be such that they were deflected by a weak magnetic field. Ewers found (Phys. Zeit., March, 1906) the δ rays of polonium to possess a speed of 3.25×10^8. With these may be compared Lenard's estimate, viz, 10^8, of the speed with which the ions leave a plate struck by ultra-violet light. It seems probable that we have here a critical speed for the electron. Below this it is not able to leave the parent atom. If its velocity exceeds the critical amount it possesses powers of penetration and of causing ionization, the extent of these powers depending on the excess.

The existence of a common speed for all δ rays may, of course, imply that the ejection is not directly effected by the ionizing agent, but that the latter simply precipitates the discharge. A man running through a battery might pull the triggers of some or all of the guns which it contained, and the velocity of the shot would not depend on the strength of the man, nor the rate at which he ran, nor how much energy he spent in the transit. And so it may be understood why δ rays are projected at a speed which is independent of the nature of the agent, as has been said above. So also it appears to be independent of the intensity of the agent's action. Fuchtbauer found the velocity of the δ rays produced by canal rays to be independent of the intensity of the primary rays; Lenard found the same for ultra-violet light.

In my own experiments on the α rays (Phil. Mag., March, 1907), I have brought forward evidence to show that the amount of ionization produced in an atom is proportional to the volume of the atom approximately. Taking this, in conjunction with the rule that the ionization produced in a gas is nearly proportional to the inverse of the speed, we have the very simple, if approximate, law that the ionization produced by an α particle in any atom under any circumstances is inversely proportional to the time spent inside the atom. This appears to point to the ionization as purely a trigger effect. Not that the α particle spends no energy in the atom; it is clear it must do so, since its speed is gradually reduced, but there is not a direct connection between the energy spent and the number of ions produced. But whatever energy the ionizing agent may spend, or in whatever way it may spend it, it seems likely that the issue of the δ particle is the result of some disruption in the atom, or subatom, which is the same for all atoms and under all circumstances.

If we turn our attention now to all secondary radiation other than the δ rays, it seems to be, in general, a rough reflection or scattering of the primary. Allen has shown that there is only a little less velocity in the secondary rays than in the primary β rays, or in the tertiary than in the secondary. McClelland has measured the total ionization produced by the secondary as compared with the primary β radiation; and since he used a small ionization chamber with which he explored the whole space traversed by the secondary rays, which chamber the secondary rays would, as a rule, completely cross if they entered it, it may be taken that he really compared the number of β particles in the secondary beam with the number of those in the primary. The numbers which he obtained varied from 15 per cent to 50 per cent, according to the substance, which is the order of things we should expect if the secondary were simply scattered primary radiation. Again, the loss of velocity of the cathode particles, which is found to occur on scattering at a plate, presuming the secondary

radiation to be scattered primary, is just what we should expect. In the case of the α rays no secondary radiation other than δ rays has been found; but a small reflection of canal rays has been observed, e. g., by Fuchtbauer. (Phys. Zeit., March 1, 1906.) Barkla has shown that the secondary radiation produced by X rays consists in part of scattered primary radiation, especially when the surface struck is of material whose atomic weight is low. The only cases in which a secondary radiation appears that is neither δ radiation nor reflected primary rays are those in which β rays are produced at the impact of X or γ rays, and in which X rays are produced by cathode rays. It is remarkable that in the former of these cases there is very great difficulty in accounting for the high speed which is possessed by the secondary radiation, caused by X rays and γ rays. (Wien, Ann. d. Phys., December 28, 1905.) It may well be that further research will bring these cases into better agreement with the rest.

The next question which it is interesting to consider in relation to the various types of radiation is that of the law of absorption in passing through matter.

Absorption in the case of the material radiations appears to be due to two main causes: Loss of energy, which causes a gradual loss of speed, and scattering, which means a diminution in the number of particles in the primary beam. There is a possibility of a third, viz, absorption of the flying particle by an atom which it is traversing.

In the case of the α particle, I have shown that the first of these causes operates alone, so that the particle pursues a rectilinear course throughout its career. (Australasian Association for the Advancement of Science, January, 1904; Phil. Mag., December, 1904.) It is the absence of any effective amount of scattering that makes the study of the motion of an individual α particle comparatively simple. The loss of energy in traversing an atom, or more exactly the probable loss in crossing a given space occupied by an atom, is nearly proportional to the square root of the atomic weight, and the effects appear to be exactly additive.

On the other hand, if we consider a stream of β particles projected into matter, and attempt to find the history of their motion, we are faced with a problem of great complexity. If we look for an answer expressed statistically, we must find the number of particles in each unit volume of the absorbing matter as a function of the time, the velocity, and the direction of motion. If, on the other hand, we try to follow the motion of any one particle, we must find the chance that the particle considered has any particular position, velocity, and direction of motion at any given time; which is really equivalent to finding the function just mentioned. Moreover, the data are very uncertain. We know so little of the interior of the atom that we are unable to say with what forces the electrons will be influenced when it

penetrates within; whether, for example, we may neglect the action of the positive electricity of the atom, and consider only the electrons as repelling the β particle with a force varying as the inverse square of the distance, or whether we are to consider positives and negatives arranged in doublets, whose moment will be the important power, and whose law of attraction will not be that of the inverse square. It is a certain simplification to suppose that scattering is mainly responsible for the fading away of a stream of β particles. The experiments of Allen, McClelland, and others show that the secondary radiation has a velocity not much less than that of the primary; and, therefore, that this simplification is justifiable; though, clearly, it can not be pushed too far. This allows us to concentrate our attention on the deflections of the particles only; but even then the difficulties are still immense. It is not like any problem in the kinetic theory of gases, for there we deal with established conditions: here with a gradual development from initial conditions.[a]

But if we turn from the theoretical to the experimental investigation we find a much more encouraging prospect. The experiments of Lenard are practically a complete graphical solution of the question. (See Taf. IV, Wied. Ann., Bd. 51.) We know that an assemblage of atoms behaves just the same in respect to these radiations when it is condensed in a solid or spread out as a gas. Thus the sketches which Lenard gives us showing the way in which the cathode rays diverge from a small window and scatter in going through various gases at different densities must be quite applicable to solids also.

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[a] In his "Conduction of Electricity through Gases," 2d edition, p. 376, Professor Thomson investigates the motion of a stream of β particles through an absorbing layer. It appears to me—I say it with very great diffidence—that the solution does not take a true account of the facts. The solution may be stated briefly thus: Taking u, v, w as the components of the velocity V of the moving corpuscle, an expression is found for the probable change in u at the next encounter. Calling this change δu, we have $\delta u = -uK$, say where K is a function of the mass of the corpuscle, the effective mass of the electron of the absorbing body, the velocity V of the corpuscle, which is taken as constant, the atomic charge, and the shortest distance between two corpuscles in the atom. K is then multiplied by the probable number of encounters in moving a distance δx along the axis of x, from which follows an exponential law for u in terms of x. It seems to me, in the first place, that, assuming such a multiplication to have any meaning, the proper factor should have been greater than that adopted in the proportion of V to u, for in advancing a distance δx along the axis of x the corpuscle moves a distance $V\delta x/u$, not δx. If this change is made, the exponential form disappears from the answer. But, apart from this, it does not seem that the step is justifiable at all. It is tantamount to putting the corpuscle back in its old track after each encounter, and is equivalent to neglecting the existence of the function mentioned above, and the absolute necessity of finding it.

Lenard found that his results could be accounted for on the supposition that there was an absorption according to an exponential law, over and above the weakening due to spreading from a center.

If a β particle or cathode particle were liable to complete absorption by an atom which it entered, such an exponential law would result at once. As a matter of fact, it looks as if several violent deflections might take place before the final disappearance of the particle's activity. It looks, also, I think, as if deflections were usually not at all great during the progress of the particle through the atom, but were apt to be severe when they did happen, as if, in fact, the field of force which deflected the particle was strong but circumscribed. This would happen if the positives and negatives were arranged in doublets. When a particle is deflected from a beam crossing a thin plate, it starts off on a new path which leads much less directly to the open air, and its velocity is somewhat diminished. It may be, therefore, that the infrequency but severity of the particle's encounters makes it possible to look upon each encounter as an absolute, or at least a definite, loss to the stream, so that an exponential law results.

Certainly the application of this law to the interpretation of experiments has had very great success, both in respect to cathode and to β and γ rays. As examples of the latter we may take Rutherford's determination of the absorption of the β rays of uranium and Godlewski's similar determination for actinium. (Jahrbuch der Rad. und Elek., Bd. III, Heft 2, p. 159.) In experiments of this kind the radiating material is spread evenly on a level surface, and sheets of absorbing material are placed upon it. The ionization produced in the space above the sheets is compared with the thickness of the sheets, and the two variables are found to be connected together more or less exactly by an exponential law. There is some difficulty in determining whether such measurements give more nearly the number or the energy of the stream of particles which emerges from the plate, as Rutherford ("Radioactivity," 2d ed., p. 134) and Thomson ("Conduction through Gases," 2d ed., p. 375) have pointed out. The point was also discussed in my address to Section A of the Australasian Association for the Advancement of Science, Dunedin, 1904, page 69. There is also an uncertainty due to the application of a formula to radiation from an assemblage of points which is really only applicable to a plane wave, or a stream moving normally to the plate. If a point source of radiation is placed below an absorbing plate of thickness d, and there is a true coefficient of absorption λ, the fraction that emerges from the further side of the plate is not $e^{-\lambda d}$; much of the radiation passes obliquely through the plate and is absorbed to a greater degree

than that which passes normally. This has often been pointed out, e. g., by N. R. Campbell (Phil. Mag., April, 1905, p. 541), who also gives some figures from which the proper curve of absorption may be drawn. I am not aware, however, that it has been noticed that the form of the absorption curve, which is far from an exponential curve for a thin radiating layer, approximates much more closely to it for a thick radiating layer. And it is interesting to find that the experimental curves which are most nearly exponential are those for which the layers of radioactive material were thick compared to the penetration of the rays under investigation. As examples, we may take those of uranium and actinium already mentioned. On the other hand, the curve which H. W. Schmidt (Ann. d. Phys., Bd. XXI, 1906, p. 651) has obtained for the β rays of RaC, the radioactive material being deposited in a very thin layer on metal foil, shows just about the amount of departure from the exponential form which is to be expected if the absorption is truly exponential, and there is only one absorption coefficient, not two, as Schmidt has suggested.

The following figures give the proportional amount of the original radiation which passes through a plate of thickness n/λ, where λ is the absorption coefficient: (1) for a thin layer; (2) for a thick layer. The figures are also given, for the sake of comparison, for the case of a plane wave, or a pencil of rays passing through the plate normally.

n.	Radiation from thin layer.	Radiation from thick layer.	Plane wave (purely exponential).
0	1.000	1.000	1.000
.1	.723	.834	.905
.2	.573	.702	.819
.3	.467	.600	.742
.4	.387	.510	.671
.5	.323	.437	.607
.6	.274	.378	.548
.7	.235	.328	.498
.8	.200	.283	.450
.9	.171	.248	.406
1.0	.145	.214	.368

The absorption of a material used in a thin sheet naturally appears greater than the absorption when the thickness of material is increased, because the rays which are moving obliquely are absorbed first.

The absorption of γ and X rays appears to follow a purely exponential law so far as experiment has been made. The δ rays are absorbed by molecules immediately on their production.

Having thus discussed certain properties of the various rays which do exist, it seems interesting to make an attempt at the estimation of the properties of some rays which might exist, though the fact has not been proved as yet. Radioactive substances emit both positive and negative particles. It does not seem at all out of place to consider the possibility of the emission of neutral particles, such as, for example, a pair consisting of one α or positive particle and one β or negative particle. The recent additions to our knowledge of the laws of absorption of α and β particles give us some grounds on which we may attempt to found an estimate of the properties of such pairs.

We know that the α particle moves in a rectilinear course throughout its whole range, and passes through the atoms which it encounters without deflection. It does not pursue a course which is straight on the whole, but zigzag in detail; the direction and amount of a particle in motion are the whole characteristics of that motion at any instant, and no memory of any previous motion exists. If, therefore, a particle pursues a straight line in its motion as a whole, it must keep to that line entirely and make no excursions from side to side. We must, therefore, suppose that an atom, or at least an α particle, endowed with sufficient speed, can pass directly through another atom without appreciable deflection. The α particle loses speed as it penetrates atoms in this way; and there can be little doubt that its charge, that is to say, the field which is about it, is a main cause of this loss of energy. But if a β particle is associated with the α particle so that the tubes of induction pass from one particle to the other, and the field is greatly contracted, it would seem that the chief cause of the stopping of the α particle has been removed.[a] The penetrating power of a pair might be very great indeed, and its ionizing power correspondingly reduced; for, although there does not seem to be a direct connection between energy spent and ionization produced, there can be no doubt that the two are simultaneous. The limitation of the field of the pair would depend on its moment; if the latter were small, that is to say, if the positive and negative were close together, the field would be more circumscribed. It is, therefore, possible to provide for pairs to have varying penetrating and ionizing powers; a pair of small moment being a good penetrator but a bad ionizer. Such a pair would be incapable of deflection by magnetic or electric fields, and would show no refraction. It is conceivable that it might show a one-sided or polarization effect, for if it were ejected from a rotating atom it would itself possess an axis of rotation.

[a] See also Rutherford's "Radioactive Transformations," p. 272.

When X rays were first investigated, and again when γ rays were discovered, it was often suggested, in each case, that the radiation might consist of material particles. Röntgen himself proposed in the third of his memoirs a theory of this nature. But it was always felt that the difficulty of accounting for the great penetration of these radiations was insuperable. It seems now that this difficulty was quite exaggerated, and even imaginary. It does not appear out of place, therefore, to reconsider the position in the light of more recent knowledge.

Assuming, then, that the neutral pair has great penetrating, but weak ionizing powers, is uninfluenced by magnetic or electric fields, and shows no refraction, it does so far conform to the properties of the γ ray. And, further, if it has any moment at all, and therefore any external field, it may at last suffer some violent encounter which will resolve it into a positive and a negative, an α and a β particle. Of these the β particle would be the one possessed of much the greater velocity, and would appear as a secondary ray. Thus, in the neighborhood of the point of impact, an ionization would appear of much greater intensity than anything produced along the track of the pair itself. So Becquerel has found the action of the γ rays on a photographic plate to be almost entirely due to the secondary rays which they produce. On this view the appearance of the β secondary ray would be really a scattering of the incident ray, and this would make the γ ray fall into line with other radiations whose secondary radiations are either scattered primary or δ rays.

If the gradual disappearance of a stream of γ radiation were caused by collision in this way, the number disappearing in any unit of length of the course would be proportional to the total number in the stream, so that an exponential law would result.

It appears, therefore, that all the known properties of the γ rays are satisfied on the hypothesis that they consist of neutral pairs.

If the γ ray is material and contains an α particle, this fact must be considered in reckoning the number and magnitude of the steps from the atomic weight of radium to that of lead. It has been suggested to me by my colleague, Doctor Rennie, that the rayless changes of Ra may really be accompanied by the emission of neutral pairs of very small moment. This adds another unknown factor to the calculation. The energy involved in such emissions might be quite small, and, moreover, if pairs can be taken up into atoms, so as to form new atoms, the whole of the energy may not appear as heat.

It is interesting to carry the speculation a little further and to observe that a pair possessing a very circumscribed field might cause little or no ionization, and be capable of very great penetration. Its

end might be incorporation with an atom traversed. Professor Rutherford has suggested to me that such a fate may befall the α particle at the end of its range. On this view it would be possible for a portion of a disintegrating atom to break away, to pass over an appreciable distance, and finally to become part of another atom, the atomic weight of which would be thereby increased. Internal atomic energy might be transferred at the same time. For if we suppose that it is possible for some of the internal energy of an atom to be set free, and recent discoveries seem to compel the supposition, then we must also consider it possible for atoms to withdraw energy from circulation and add it to their internal store. If, therefore, the handing of neutral pairs from one atom to another is a process which actually occurs, then matter and energy may be continually transferred from atom to atom without our being aware of it: the whole operation may take place in a world apart. We can not follow it by radioactive tests, for the ionization is so feeble; nor chemically, because the rate of atomic change is so slow; nor thermally, because the energies appear at no stage in tangible form.

Since the properties of γ rays are amongst the properties of X rays, an hypothesis which will suit one form of radiation will also so far suit the other. But we know much more about the latter form of radiation than we do about the former. It is of interest, therefore, to consider the extent to which our additional knowledge can be fitted to a neutral pair hypothesis. It is true, of course, that the ether pulse theory has been most ably developed, and is now widely accepted. Nevertheless the evidence for it is all indirect: and indeed some of it is, I think, a little overrated. It is quite possible that ether pulses may not, after all, constitute the bulk of Röntgen radiation. If, therefore, there is anything to be said in favor of any other hypothesis, it seems right that it should be said and considered.

Let us therefore for the moment suppose the X rays to consist mainly of a stream of neutral pairs.

We have at once an explanation of the absence of deflection in electric and magnetic fields and of regular reflection and refraction. There should be great penetration, whose amount might vary with the moments of the pairs, or the velocity, if the latter were a variable. We can understand that a pair which struck a light and yielding atom might be returned unchanged; yet if it struck a heavier and more resisting atom it might be disarranged so as to acquire a greater moment, and thus to become a better ionizer, but more readily absorbed; or it might be shattered altogether, giving rise to a secondary ray of the cathode type. The softer the ray, i. e., the greater the moment of the pair, the more readily might this be done, and the

lighter the atom that would do it. (See J. J. Thomson on Barkla's researches, "Electrician," April 5, 1907.)

In order to explain these known effects on the ether-pulse theory it is necessary to suppose that in light atoms the corpuscles are not appreciably acted on by forces due to other corpuscles, but that in heavy atoms there is a strong influence of this kind. In the former case the thickness of the secondary pulse is the same as that of the primary; in the latter it is not. It is also necessary to suppose that when the atom is heavy enough to cause a modification of the primary radiation, it differs from a light atom in such a way that the pulse can cause cathode particles to be ejected at a speed due to thousands of volts, whereas this is impossible with light atoms.

If the cathode particles in the X-ray tube so affect the motion of an atom which they strike as to make it throw off a pair, then the plane of rotation of the pair will be the same as that of the atom from which it has come, and will contain the direction of the translatory motion of the pair. The pair will therefore be able to show polarization effects, and if such a pair falls upon a reflecting surface, it is not unreasonable to suppose that it is liable to be taken up only by an atom revolving in the same plane, and sometimes to be ejected again. Thus its subsequent rotation and translation will continue to take place in the one plane. The tertiary ray will therefore be strongest when it is in the same plane as the primary and secondary; and this is Barkla's polarization effect.

If the X ray is an ether pulse, it is difficult to understand why the spreading pulse affects so few of the atoms passed over ("Conduction of Electricity through Gases," pp. 294–297), why the high-speed secondary cathode rays are ejected with a velocity which is independent of the intensity of the pulse, and why it should be able to exercise ionizing powers when its energy is distributed over so wide a surface as that of a sphere of say 10 or 20 feet radius. All these phenomena are more simply explained if we suppose the ray to be a neutral pair which has only a local action, i. e., can only affect the molecules on its path, which can penetrate to great distances in air, losing little speed as it goes, and which gives rise to a cathode ray when it is broken by impact.

It seems to me that the material-nature hypothesis shows to advantage when we consider the secondary radiation of the X rays. The rays cause the emission of cathode rays whose speed averages about 5×10^9. (Dorn.) We have no experience of any ether wave causing the emission of any but δ rays, i. e., electrons with a speed of about 10^8. It can hardly be said that differences in intensity of the ether pulse can account for this remarkable contrast, for the speed of the δ rays caused by ultra-violet light has been shown by Lenard to be independent of the intensity of the light, and the ve-

locity of the X-ray secondary radiation does not depend on the intensity of the X rays. It may be argued that the breadth of the pulse is the prime factor, on the grounds that Lenard found the velocity of the δ rays due to ultra-violet light to depend somewhat on the nature of the light; but it is hard to believe that a diminution of the width of the pulse, no matter how extreme, can increase the energy of the ejected electron about a thousand times.

But if we regard the secondary radiation as the result of the break-up of a neutral pair, the high velocity of the ejected electron (5×10^9) may be more readily explained. The action must be entirely different from that of ultra-violet light.

It is difficult to found any arguments for or against either theory on considerations of the relative energies of the original cathode stream, the X rays, and the secondary rays, for if the energies of any transformation do not balance, it is easy to square the account by postulating either some release of the internal energy of the atom, or the reverse, viz, the absorption of energy by the atom involving a disappearance of the visible energy. On the neutral-pair hypothesis the cathode rays would probably have a trigger action, and the pairs would draw their energy from that internal to the atom; it might not be necessary to invoke the aid of internal atomic energy in order to account for the energy of the secondary radiation. In the case of the ether-pulse theory it is necessary to suppose that the secondary radiation derives its energy from the atom's store. ("Conduction of Electricity through Gases," p. 321.) It is not clear whether such a call must also be made at the transformation of cathode into X rays. The whole question, taken into conjunction with the diffraction experiments of Haga and Wind, has lately been under discussion by Wien (Ann. d. Phys., XVIII, p. 991, 1905; XXII, p. 793, 1907) and Van der Waals, jr. (Ann. d. Phys., XXII, p. 603, 1907), but no definite conclusion is reached.

It is not easy to see how the irregular stoppage of the cathode particles can give rise to pulses of sufficient definition and uniformity to show diffraction. It would be easier to explain such an effect as the result of uniform disturbances arising when pairs of uniform nature are torn from the atoms of the anode.

On the ether-pulse theory hard X rays are supposed to be thin pulses, soft rays to be thick pulses. Swift cathode particles are supposed to take less time in deflecting and stopping than slower particles, and therefore to give rise to thinner pulses. On the other theory we must suppose that the rays are hard when the moments of the pairs are small, or possibly that hardness is due to high velocity. If the former is the case, it may be that fast cathode particles spend less time within the anode atoms than the slow ones do, and therefore disarrange the pairs less before they are ejected.

There is another entirely different argument, which seems to support the neutral-pair hypothesis.

The α, β, and γ rays all ionize the gases which they traverse. It has just been shown by Kleeman[a] that the ionization per atom due to β and γ rays is nearly proportional to the ionization per atom due to α rays (and, therefore, approximately proportional to the volume, as I have shown, Proc. Roy. Soc. of S. A., Oct., 1906; Phil. Mag., March, 1907). The figures for the heavier atoms are rather larger for the β than the α rays, and still larger for the γ rays. It is known that the ionizations due to X rays differ considerably from those due to γ rays when the X rays are soft, but approximate to them when the X rays are hard.

All this fits in excellently with the theory that all four types of rays are material. Take the α particle first, since its circumstances are the most simple. It moves directly through the atoms, without scattering or transformation. It liberates ions in the form of δ rays as it goes, approximately according to the volume law. The β ray is also a charged particle, and it is readily to be supposed that it would, if its whole motion were rectilinear, liberate ions according to the same law (comparing atom with atom) as the α particle, though the numbers would be less. But the β particle is liable to scattering, and each act of scattering generally implies an increase in the path of the particle in the gas, and increased ionizing power since its speed is a little diminished. Now, scattering is proportional to the atomic weight, whilst the ionization is more nearly proportional to the square root of the atomic weight. Thus a heavy atom is the cause of more than its proper amount of ionization; and so we find in Kleeman's table that the ionizations of the atoms Cl, Br, and I are rather higher than in the case of the α particle. Again, the γ particle is liable to resolution into its elements, with a relatively large amount of ionization. Since this transformation is chiefly effected by impact with heavy atoms, these latter will be the cause of a disproportionately large ionization, as compared with the α rays; and this is also shown by Kleeman's figures. Passing on to X rays, we find a further illustration of this effect, until we come to very soft rays, when we find that the heavy atoms are the occasion of exceedingly large ionization. ("Conduction of Electricity through Gases," 2d ed., p. 300.) There is a good continuity in all these phenomena, with gradual divergences just where we should expect them. The α, β, γ, and X rays all produce the same primary ionization, comparing atom with atom, and differ only in the effects due to scattering and transformation;

[a] Mr. Kleeman has been good enough to inform me of his results by letter; but I believe I am at liberty to quote them, since he has, I understand, recently read a paper on the subject before the Royal Society.

that is to say, differ only as regards their production of secondary ionization. Now, the α and β rays are certainly material particles, possessing electric fields. There is, therefore, a reasonable argument that the γ and X rays are also material, and possess electric fields. This is the case if they are pairs, and the smaller the moments are the more circumscribed are the fields and the less the ionization and the loss of energy.

If the X rays contain ether pulses only, it is difficult to see why their effects should run so exactly in parallel with those of the α and β rays.

It has been announced by Marx, as the result of a most ingenious experiment (Phys. Zeit., 1905, p. 268), that Röntgen rays move with the velocity of light. It is extremely improbable that material particles can possess such a velocity, and the experiment of Marx might seem at first sight to be strongly against any material nature of the X rays. But it is not clear that Marx really measured the velocity of a radiation causing the emission of high-speed electrons, which is the characteristic feature of X rays. All that he showed was that the bundle of X rays contained radiation moving with the speed of light and capable of exciting δ rays. To see this it is necessary to consider briefly the details of the experiment.

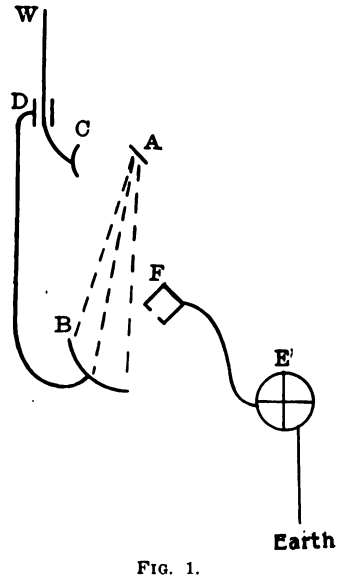


FIG. 1.

An electric pulse is made to travel along a wire, W, as shown in the accompanying sketch. When it reaches the cathode, C, cathode rays are driven against the anode, A, and X rays are given out, some of which travel toward the saucer-shaped electrode, B. At the focus of B is a small Faraday cylinder, F, connected to an electrometer, E. A small impulse is derived from the wire, W, by electrostatic induction at D, and travels down to B. If the various distances and wire lengths are properly adjusted, so that the X rays arrive at B at the same moment as the derived impulse, electrons are liberated at B by the rays, and guided by the impulse into the cylinder, F, and thence to the electrometer. If now the distance of the X-ray bulb from B is altered, say, by an increase of 10 cm., the wire from D to B has to be lengthened by 10 cm. Thus, according to Marx, the X rays travel with the same velocity as the impulse in the wire, and therefore with the velocity of light.

But it is to be remembered that the electrons which are liberated by X rays have an initial velocity averaging about 5×10^9 per sec., i. e., a speed due to thousands of volts, and are scattered in all directions from the surface on which the rays fall. Neither the weak impulse applied to B by the wave coming along the wire, DB, nor the peculiar form of the surface, B, could have any sensible effect in the way of guiding these fast-moving electrons into the cylinder, F. Only slow-moving electrons or δ rays could be guided by such means. It is no doubt true that X rays do liberate a certain number of δ rays, but it is clear that the experiment of Marx is quite consistent with the hypothesis that the X rays are complex, and consist in part of ether pulses traveling with the velocity of light, and producing δ rays, and in part of material particles, or pairs, traveling at a speed as yet undetermined, and exciting high-speed cathode rays. It would be reasonable to expect that a stream of pairs should be accompanied by ether pulses which had their origin at the time and place where the pairs broke away.

It is possible that the example of the α particle shows that a pair can not possess a velocity greater than 10^9, since at a higher speed it would be stripped of an electron, and become an α particle. J. J. Thomson has suggested that at this critical speed the α particle becomes electrically neutralized by the attachment of an electron. Presumably such a pair would then go on as a γ ray. No such consequence has been observed; and on the present hypothesis it would be better to suppose that the α particle ends its career by being taken up by an atom, as Rutherford has suggested. There is no reason to suppose the γ ray or X ray to possess any great speed, so as to give it enough penetrating power. The latter might depend rather on the limitation of the field of the pair; and a sufficient range for the velocity can be found between the minimum speed of the α particle and the maximum speed necessary for penetration, which appears to be about 10^8 for a charged particle, but may be less for one without charge. A moderate speed would account for the reflection or scattering of the X ray, and would indeed be necessary for this purpose.

To sum up, it is clear that a stream of X rays contains some ether pulses, but it is not easy to explain all the properties of X rays on the ether-pulse theory. The explanations are easier if the rays are supposed to consist mainly of neutral pairs; and the existence of such pairs is not improbable *a priori*.

[Added July 18, 1907.]

Since this was written several important papers have appeared, with which the outlined theory seems to me to be in harmony.

I have supposed it possible for positive electrons to be detached from atoms of matter in the X-ray tube and to be sent out in company with negative electrons, one of each going to the formation of

a neutral pair. Now, J. J. Thomson has just shown (Phil. Mag., May, 1907) that the canal rays consist of positive electrons, which may be H or H_2 or He, according to circumstances, and that these appear no matter what the material is in the tube. It will be remembered that Villard (Ions, Electrons, Corpuscules, p. 1022) was so impressed with the continual presence of hydrogen in vacuum tubes that he supposed the cathode particles to consist of hydrogen, until accurate measurements of the mass and velocity of the particles were made. He was largely influenced by the reducing action of the rays. After all, it may be that H is produced where they strike, and that Villard's observations can be explained in this way. Sir William Ramsay (Journ. Chem. Soc., May, 1907) has shown that there is an excess of hydrogen in water decomposed by radium emanation; but the circumstances are too complicated to make the connection more than a possibility at present.

H. W. Schmidt has arrived at the conclusion (Phys. Zeit., June, 1907) that the "secondary" radiation caused by β rays striking aluminium consists of scattered primary rays. This is in agreement with the argument stated above. He has also shown that undeflected β particles lose no speed in passing through a metal plate. This implies either that the energy required to produce ions does not come from the β particle or that the β particle does not produce ions until it is deflected. There seem several difficulties in the way of the latter supposition, though it is, of course, a possibility. It seems to me probable that the β particle rarely produces more than one ion from a traversed molecule, but that an α particle may produce many, and that initial recombination is to be explained in this way. Kleeman has pointed out, in his Royal Society paper, that an α particle which has lost several ions has not yet been observed; but it is to be remembered that such a molecule would probably dissociate at once, and it is well known that the α particle does produce dissociation.

NOTE.—In a supplementary paper contributed to the Royal Society of South Australia and dated January 2, 1908, Bragg has described certain experiments which he has performed with the object of testing the hypotheses of the original paper.

He argues that on the ether-pulse theory there should be perfect symmetry in the secondary radiations on the two sides of a thin plate through which a stream of γ rays is passed normally. He finds, however, that such an expectation is completely contradicted by experiment.

On the other hand, he shows that on the neutral pair theory the quantity of secondary cathode radiation which is excited on the near side of the plate, i. e., the side on which the rays are incident, should depend on the atomic weight of the material of the plate according to the same law as that which holds for the secondary cathode radiation due to β rays.

It is well known that this is actually the case. Again, he shows that on the same neutral pair theory the quantity of secondary radiation which is excited on the far side of the plate, i. e., the side from which the rays emerge, should

be the same for all substances, assuming (1) that the absorption of γ rays depends only on the density of the material traversed and not on its atomic weight; (2) that the β rays behave like the γ rays in this respect; (3) that the γ rays are not liable to selective absorption.

He then shows by experiment that the "emergence" radiations show no sign of following the β ray law, as the incidence radiations do; that they are of the same order for all substances, and that the observed differences promise to be readily explained when proper account is taken of the imperfections of each of the three assumptions mentioned above.

He further discusses the possibility that the cathode particle of the X-ray tube may become an X ray by picking up a positive of small mass at the anode, and may afterwards by dropping the positive become the secondary cathode ray, the speed remaining approximately the same throughout.

PROGRESS IN ELECTRO-METALLURGY.[a]

By JOHN B. C. KERSHAW.

The electro-metallurgical industries are the growth of the last twenty years, but in that period very remarkable progress has been made. Only one industry existed prior to 1886, namely, that of copper refining. This was carried on in a few works upon an extremely limited scale of operations. To-day the electrolytic copper-refining industry is second in importance only to that of copper smelting, and over one-half of the world's production of copper is submitted to the former process. The manufacture of aluminium, calcium, carbide, carborundum, ferroalloys, and sodium are other important and expanding electro-metallurgical industries, while the application of the electric furnace to steel refining is a new development which may lead to very important changes in the iron and steel industries, for, in conjunction with gas engines and dynamos, it may serve as a means of utilizing the enormous power now lost in the waste gases from our blast furnaces.

The following pages deal with the various electro-metallurgical industries in alphabetical order, describing briefly the processes or methods in use and the extent to which these methods have been applied upon an industrial scale.

Aluminium.—The manufacture of aluminium by the electrolytic method was commenced at New Kensington in America in the year 1888, and at Neuhausen in Switzerland in the year 1889. The processes were worked out independently by Hall in America and by Heroult in France, but as now operated they are practically identical, and consist in the electrolysis, with carbon electrodes, of aluminium oxide held in solution in a fused bath of cryolite and fluorspar. Since the introduction of the electrolytic method of manufacture in 1889 the production of aluminium has increased from 85 tons to 12,000 tons in 1906. The following tabular statement shows the gradual

[a] Reprinted, by permission, from the Engineering Magazine, New York, October and November, 1907.

increase in output and fall in price which has marked the industrial development of the electrolytic process:

Year.	Production.	Price, pence per pound.	Year.	Production.	Price, pence per pound.
	Tons.			*Tons.*	
1885	3.12	600.0	1896	1,755.00	17.0
1886	14.80	500.0	1897	3,327.00	17.5
1887	22.50	400.0	1898	3,953.00	16.2
1888	39.40	250.0	1899	5,459.00	16.2
1889	85.20	125.0	1900	7,192.00	16.0
1890	174.50	100.0	1901	7,420.00	15.5
1891	345.50	125.0	1902	7,750.00	15.5
1892	485.00	82.0	1903	8,102.00	15.5
1893	713.00	----------	1904	8,550.00	15.5
1894	1,057.00	25.0	1905	9,000.00	16.0
1895	1,129.00	22.0	1906	12,000.00	21.4

NOTE.—The production is given in tons of 2,240 pounds and the price in pence per pound. From 1902 onward the production figures are estimated, and from 1897 to 1904 the figures for price are based on the American values.

The manufacture of aluminum is now carried on in a number of works, controlling over 84,000 horsepower. Details of these so far as they are known, are given below.

Name of company.	Locality of works.	Horsepower.
1. British Aluminium Co	Foyers, N. B	*5,000
	Norway	*10,000
	Switzerland (in course of erection)	*45,000
2. Société Electro-Metallurgique Française	La Praz	7,500
	Gardannes	7,500
3. Compagnie des Produits Chimiques d'Alais	Calypso	10,000
	St. Felix	2,500
4. Aluminium Industrie Aktien-Gesellschaft	Neuhausen	5,000
	Rheinfelden	5,000
	Lend Gastein	15,000
5. Compagnia Italiana	Pescara	*3,000
6. Pittsburg Reduction Co	Niagara Falls	10,000
	Shawinigan Falls (Canada)	5,000
	Massena, N. Y	12,000

* On the authority of the Revue Industrielle, 1907, p. 222, as quoted in L'Industria.

Assuming that 4 horsepower are required for one year, to produce 1 ton of aluminium, the aggregate power available in these works would suffice to produce 35,000 tons of the metal per annum. Owing, however, to the diminished power available during the summer droughts and to other causes, the maximum total of power is not available for the manufacture all the year round, and my estimate of the 1906 production is about 12,000 tons.

The past year has been marked by the expiration of five of the United States patents granted to Hall in 1889. The Heroult patents

lapsed in Europe in 1902, and the manufacture of aluminium by the electrolytic method can therefore now be carried on without the payment of patent royalties. The use of the electric current for keeping the bath in the molten state is, however, still covered in America by the Bradley electric-furnace patents, which do not expire until 1909. In that country the Pittsburg Reduction Company therefore still possess the monopoly of the electrolytic reduction process.

As regards utilization, the demand for the metal in Europe during 1906 has been in excess of the output, and the reduction plants are being extended in several of the works, in order to benefit by the higher prices now obtainable for the metal. The British Aluminium Company, in addition to the development of a new water power in Switzerland, are carrying out a very large scheme on Loch Leven in Scotland, which when completed will add enormously to their power resources in Scotland. The Aluminium Industrie Aktien Gesellschaft, of Neuhausen, are likewise developing a large power scheme on the River Navisonce in Switzerland, from which it is expected that 25,000 horsepower will be derived. A new aluminium works has been erected by an Italian company in the Valley of Pescara in Northern Italy, and is about to commence operations. In a few years, therefore, the productive capacities of the aluminium companies will be more than doubled, and it will be of interest to note whether the demand shows a similar expansion.

The metal is now being used in very large quantities for motor-car construction and for general foundry work, while the "Thermit" and "Weldite" processes also consume large quantities of aluminium in the form of powder. In every direction in which the metal has been applied with success its use has increased during 1906.

Mr. Schoop, of Paris, has worked out the details of a process for the autogenous welding of aluminium which overcomes the difficulty of finding a suitable solder for the metal. By this process aluminium sheets, rods, or tubes, of any thickness, can be welded without any difficulty, and the joints are said to be as strong as the other parts of the metal. This method of welding will probably lead up to increased consumption of the metal in many industries and to its use for larger articles and vessels than have yet been manufactured from it. Another direction in which the use of aluminium is extending is for the manufacture of pans, etc., for use in the wax-refining and jam-boiling industries, which have hitherto employed copper vessels for this purpose.

Bullion refining.—Electrolytic methods have been applied with great success on both sides of the Atlantic in the refining of gold and silver bullion, the Moebius process being used for silver and the Wohlwill process for gold. In the Moebius process a dilute solution of silver nitrate containing free nitric acid is employed as electrolyte,

while in the Wohlwill process a solution of gold chloride is utilized. In America the Philadelphia and Denver mints are equipped with electrolytic parting apparatus, and a similar installation of electrolytic baths is now being erected at the Government mint in San Francisco. Many of the American copper refineries also have an electrolytic plant for refining the silver obtained as a by-product in the copper-refining process. In Europe electrolytic refining is carried on at Frankfort by the Deutsche Gold- und Silber-Scheide Anstalt and by the Norddeutsche Affinerie at Hamburg, details of the Wohlwill gold-refining process having been worked out at the latter refinery. Electrolytic bullion refining is also carried out in Great Britain and in France, but no details of the works are available for publication. A recent improvement of the Moebius process is the use of gelatine, which gives a smooth coherent, in place of a rough crystalline deposit at the cathode.

Calcium carbide and acetylene.—Calcium carbide is obtained by heating lime and coke in an electric furnace, and it was first produced in a large scale by Willson at Spray in the United States in the year 1893. The late Henri Moissan about the same time produced this compound in his laboratory in Paris, and the European patents granted to Willson have not been upheld, owing to the earlier publication of the results of Moissan's chemical researches upon the electric furnace and its products in the " Comptes Rendus " of 1894.

The early history of the calcium carbide and acetylene industries is chiefly a record of reckless finance, worthless patents having been used for company flotations upon a large scale, with serious results for the investors and for the industry. The period culminated in 1899–1900 with a series of failures and financial " reconstructions." Since that year the companies have been slowly recovering from the effects of this unwise boom. Though acetylene gas has not displaced other illuminants to the extent that was at one time expected, it is now used for various purposes much more widely than is generally recognized, and central acetylene-generating stations are found in very many small village communities in Europe and America.

According to the most recent estimates there are now between sixty and seventy works engaged in the production of calcium carbide, and the aggregate production amounts to between 90,000 and 100,000 tons per annum, valued at £1,000,000. The United States, Italy, and France head the list of producing countries, and are also the largest consumers of carbide for acetylene-generation purposes. During the period of inflated finance several works for the manufacture of carbide were started in the United Kingdom. All of these have ceased operating, and only one small works is now active, at Askeaton in Ireland. The greater portion of the carbide consumed in the United Kingdom is therefore imported from Norway and from other countries which

POWER PLANT, LA PRAZ WORKS OF THE SOCIÉTÉ ELECTRO-METALLURGIQUE FRANÇAISE.

VAT ROOM, AMERICAN METALS REFINING COMPANY. CROCKER-WHEELER ELECTRICAL EQUIPMENT.

A CARBORUNDUM FURNACE AFTER A RUN.

produce in excess of their requirements. In France the industry is controlled by a syndicate with headquarters in Paris, and this exercises a close watch over output and price. Eleven works are reported to be still operating, situated around the following centers of cheap water power: Bellegarde, Grenoble, Nice, and Toulouse. The estimated output of these works in 1906 was 24,000 tons; the annual consumption in France is about 15,000 tons.

Germany is dependent upon Switzerland, Austria, and Norway for two-thirds of its supply of carbide, only 8,000 tons being produced at home, whilst 16,000 tons are imported. In the United States the production of carbide is estimated to amount to 25,000 tons per annum, the Union Carbide Company, with works at Niagara Falls, being the chief producers. A large new factory designed for the utilization of 10,000 horsepower is now being erected, however, in a new center in the States.

Although calcium carbide is being employed chiefly for generating acetylene for illuminating purposes, its application for production of "calcium cyanamide" is likely to lead to developments of some importance. The use of acetylene gas in the oxyacetylene blow pipe, for the autogenous welding of metals, is another application of considerable industrial importance, since temperatures can be obtained with this apparatus which approach those of the electric arc, and the size and shape of the flame are more suited for welding purposes.

Calcium.—Calcium in the metallic state is one of the latest electro-metallurgical products, the metal being produced by electrolysis of fused calcium chloride and fluoride with a rising cathode, which just touches the surface of the fused electrolyte. This method is adopted to prevent the re-solution in the molten electrolyte of the calcium deposited at the cathode. The temperature of the bath is kept at about 670° C., and the process works most satisfactorily with fresh and neutral calcium chloride. The metal is obtained in the form of an irregular rod, made up of a series of buttons, fused together. The metal is dark gray in color, of specific gravity 1.51.

Calcium is now being manufactured upon a commercial scale by the Elektrochemische Werke at Bitterfeld in Germany, under the Rathenau patents, and is being placed upon the market by the same firm. The only difficulty in the development of the new manufacture lies in the lack of applications or uses for the metal. It has been suggested that it might be used in the place of aluminium for removing the oxides from steel, but at present aluminium is the cheaper metal. For many other reduction processes calcium can not replace sodium, since its affinity for oxygen is not so great. Attempts to form alloys of calcium with copper and other metals have also failed, as one would have expected.

Carborundum.—Carborundum is the trade name given to a carbide of silicon, first made by E. G. Acheson at Niagara Falls, by heating coke, sand, and sawdust to a temperature of between 2,000° and 3,000° C. in an electric furnace of the resistance type. The product has the formula SiC, and the manufacture has grown into one of considerable importance on account of the excellent abrasive properties of the carbide. In 1892, 1,000 pounds of carborundum were produced at the Niagara works, whereas in the last year for which complete figures are available (1906) the output had increased to 6,225,000 pounds. For many years the Niagara Falls works supplied all the demand for this compound.

Another artificial substitute for emery has also appeared, in the form of an electric-furnace product called "alundum," obtained by heating bauxite to a high temperature. In order to meet the increased competition, the Carborundum Company of the United States have arranged to carry on the subsidiary manufacture of grinding wheels, abrasive tools, and materials in Germany, a new works for this purpose having been erected there in 1906.

Tucker and Lampen have recently carried out some laboratory experiments with carborundum, and have found that the temperature originally given by Acheson for its formation and dissociation are too high. According to Acheson these temperatures were over 2,500° C., while Tucker and Lampen give 1,600° to 1,900° and 2,220° C.

Copper.—The electrolytic copper-refining industry is the oldest of the electro-metallurgical industries, having been started by James Elkington at Pembrey in South Wales in the year 1869. The process and methods used by Elkington in this small refinery were similar in all respects to those in use at the present day, copper sulphate being employed as the electrolyte with raw-copper anodes and thin sheets of pure copper as cathodes. The only change has been in the magnitude of the operations. At Pembrey the electrolyte was contained in small earthenware pots, and the output was 15 hundredweight per day, or 250 tons per annum. To-day there is one refinery in America producing electrolytic copper at the rate of 350 tons per twenty-four hours, and the aggregate output of all the refineries is estimated at 400,000 tons, or 53 per cent of the total raw-copper production of the world. This enormous growth of the industry has occurred chiefly in recent years, the capacity and output of the American refineries, which contribute over 85 per cent of the total, having been doubled within the last seven years. The expansion is due partly to the great demand for a very pure copper for electrical purposes and partly to the presence of silver and gold in the American raw copper, in sufficient amount to pay for their recovery from the slimes obtained in the electrolytic process of copper refin-

ing. Thirty-four electrolytic refineries are now operated in Europe and America.

The chief progress of recent years in this industry has been in the substitution of machine for hand labor, the casting of the raw-copper anodes, and the charging and discharging of the vats by mechanical methods, now being carried out in all the large up-to-date refineries. The chief improvement on the chemical side of the process has been the addition of a small amount of hydrochloric acid to the electrolyte in the vats. This, according to Carlson, prevents the loss of silver which otherwise occurs, the insoluble silver chloride being precipitated with the slimes.

Diamantine.—This is a trade name given to a new product obtained by heating alumina with small quantities of silica to a high temperature in the electric furnace. When finely powdered and mixed with clay and water, the new material is said to form a useful

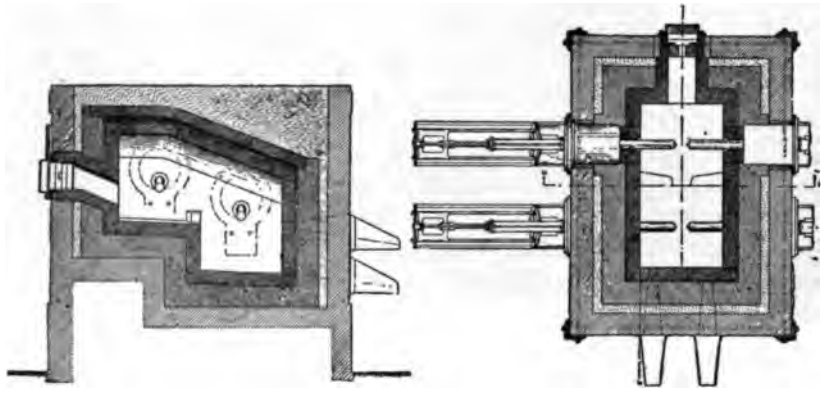


FIG. 1.—Stassano fixed type electric furnace for copper.

wash for the inside lining and walls of furnaces exposed to a high temperature. The new product is being manufactured upon a commercial scale by the Diamantine Werke at Rheinfelden, Germany.

Graphite.—The production of a hard variety of artificial graphite has been carried on since 1892 by Acheson at Niagara Falls. The method of manufacture is to form first a carbide in the electric furnace and then to decompose it by increasing the heat up to a point at which it dissociates and the second element is volatilized. Under these conditions the carbon remains in the furnace in the form of graphite. Acheson in his earlier work used coke mixed with silica or sand, but he has since found that it is simply necessary to start with ordinary anthracite coal; the impurities of this suffice to provide the second element of the carbide, and when raised to a definite temperature, these elements volatilize and leave the carbon as graphite. The manufacture has been a very successful one, and the work of the

International Acheson Graphite Company at Niagara Falls now utilize 2,000 horsepower, and produce over 2,000 tons of artificial graphite per annum. The greater portion of this output is used for electro-chemical and electro-metallurgical work, the Acheson artificial graphite having been found specially suited for electrodes. During 1906 Acheson discovered a process by which the soft variety of graphite can be produced in the electric furnace, and it is expected that this new artificial graphite will become a keen competitor of the natural variety, especially as it shows more uniformity of composition. No details of the new process of manufacture have yet been published.

Ferroalloys.—The application of the electric furnace for producing alloys of iron with silicon, chromium, manganese, tungsten, and vanadium has developed into a large and important metallurgical industry. Since Moissan's early research work, the value of these alloys for the manufacture of special steels has been recognized by expert steel makers in all countries. The manufacture of ferroalloys is carried on at present chiefly in France and Switzerland, a cheaply developed water power being essential for the commercial production of these compounds. In France, MM. Keller, Leleux & Cie. are producing ferrosilicon and ferrochrome in large amounts at Livet and Kerrousse, while the Société Electro-metallurgique Française devote a portion of their power to the same manufactures at La Praz and St. Michel. The largest works are, however, to be found in the Haute Savoie, on the borders of Switzerland, where the Société Electro-metallurgique Giroud are utilizing 18,000 horsepower for the production of a ferrosilicon, ferrochromium, ferrotungsten, and ferromolybdenum, the aggregate output of the three works owned by this company being given by Doctor Hutton as 9,000 tons per annum and the value as £360,000.

In Germany MM. Goldschmidt & Cie. and MM. Krupp are using the aluminium reduction process, in place of the electric furnace, at Essen for producing ferroalloys free from carbon.

In America the ferroalloys industry is less developed, the Willson Company, with works at Kanawaha Falls and at Holcombs Rock, Virginia, being the only producers of ferrochromium; about 3,000 tons are produced in the two works. Rossi is, however, experimenting at Niagara Falls with electric-furnace methods of producing ferrotitanium, and a new works has been erected during 1906 at Newmire, Colorado, by the Vanadium Alloys Company of New York, for the manufacture of ferrovanadium. Recent trials of ternary and quaternary steels, made with the addition of vanadium, have proved that these steels are specially suited to the demands made by motor-car work, and it is expected that in time the manufacture of vanadium steel may become a branch industry of considerable importance.

INTERIOR OF FURNACE ROOM, THE CARBORUNDUM COMPANY, NIAGARA FALLS, N. Y.

With regard to the use of ferroalloys generally, ferrosilicon is employed as a deoxydizing agent, while the other alloys are employed for introducing the rarer metals into the steel, it having been found that a more homogeneous product is obtained when the metal is introduced into the molten steel in the form of an alloy than when it is introduced in the pure state. All the chrome-steel used for armour-plate manufacture is now made with the aid of ferrochrome.

Iron and steel.—The methods of producing iron and steel in the electric furnace have been developed chiefly by French electrometallurgists, a large number of works in France having been rendered idle by the collapse of the boom in the calcium-carbide industry in 1899–1900, and new applications being required for the water-power and electric-furnace plant thus made available. The earliest trials of the electric furnace for iron and steel production date from 1899, and since that year experimental work has been carried on continuously. During the last three years the new methods have attracted the attention of steel makers, and it is now generally recognized that certain of the methods and processes have attained a permanent footing in the iron and steel industry. The Heroult and Kjellin methods of steel refining by aid of electric heat have shown the most striking development, and a large number of works in Europe and America are using these methods with satisfactory results.

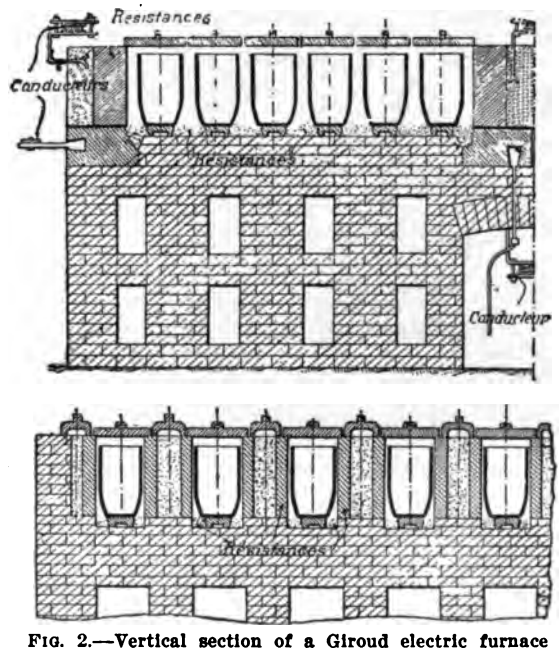


FIG. 2.—Vertical section of a Giroud electric furnace for crucibles individually heated.

The Heroult steel-refining furnace is of the crucible type, and the heating is initially effected by means of the electric arc, which forms between the surface of the slagging materials covering the metal and the two massive carbon electrodes which are suspended above it. The slag when molten is used for resistance heating, the carbons being lowered until they touch it. The impurities of the iron are removed by renewing the slag from time to time. The refining operation thus becomes a " washing out " of the impurities of the iron, by treatment

with suitable slags. When purified, " carburite " in requisite amount is added, and the crucible is tipped.

Heroult claims that with this furnace iron or steel of any degree of impurity can be refined, and that from the purified metal, a steel of any desired composition can be produced by the addition of the necessary amount of " carburite " and other ferro-alloys.

The Heroult furnace is now in operation at La Praz and Froges in France, at Kortfors in Norway, at Remscheid in Germany, and at Syracuse, New York. The Remscheid plant has been in operation since February, 1906, and is on a smaller scale than the Syracuse plant.

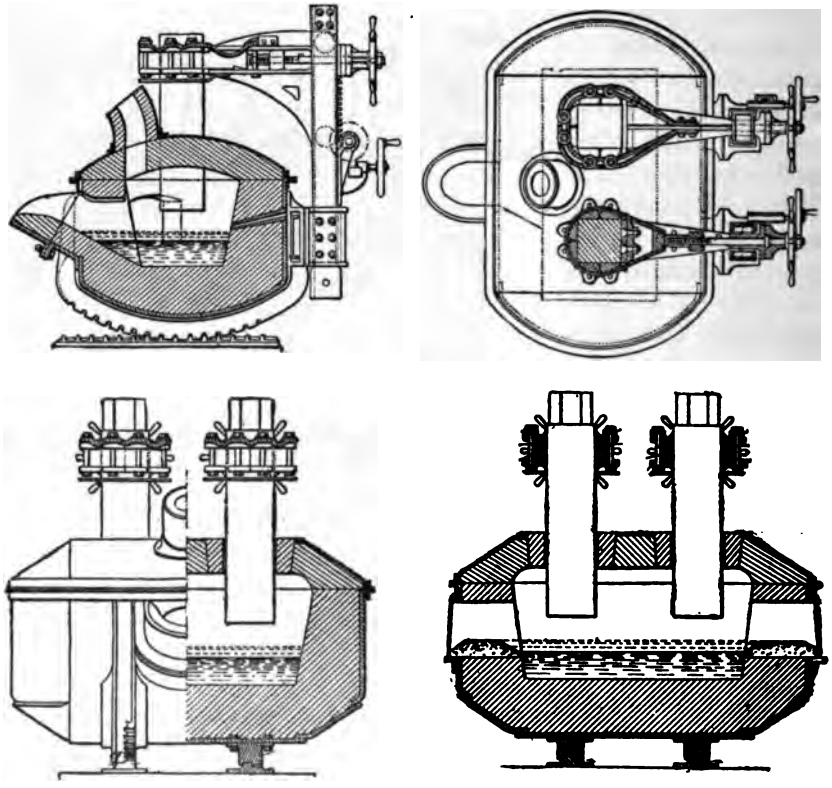
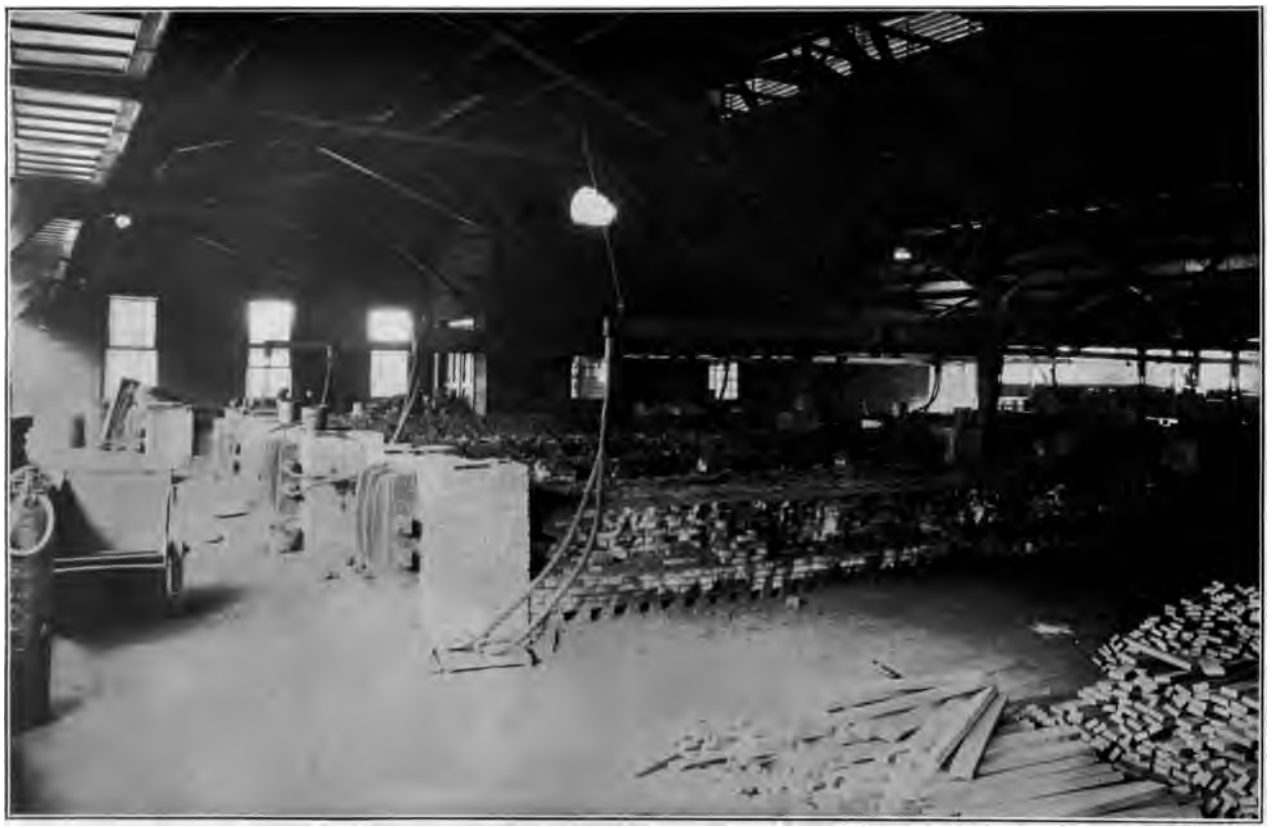


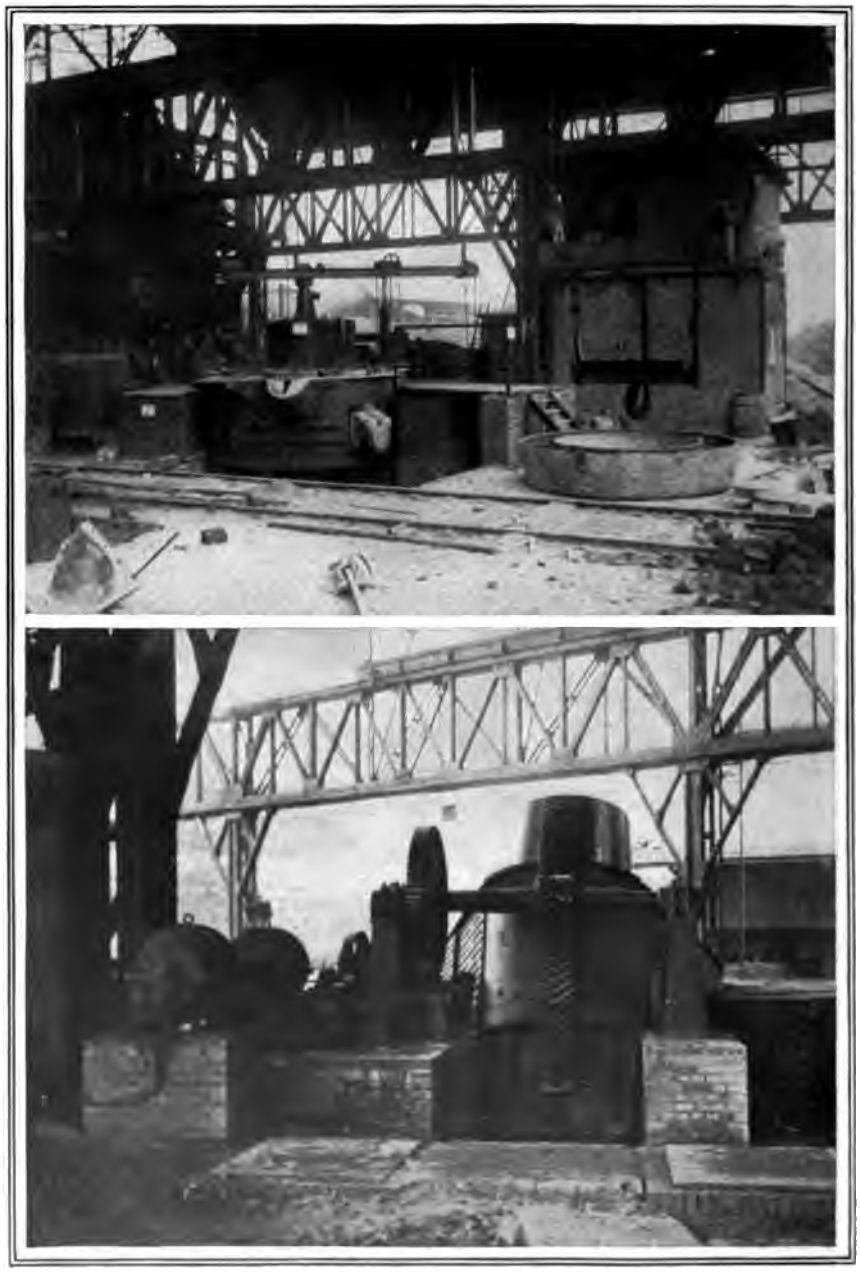
FIG. 3.—Longitudinal and transverse sections of Héroult crucible furnace.

The Kjellin furnace has been developed at Gysinge in Sweden, and differs materially from the Heroult furnace. In place of the use of direct current for combined arc and resistance heating, the Kjellin process utilizes induced currents, and the heating effect is obtained by the rapid changes in the magnetic state of the iron or steel which forms the secondary coil of the circuit. The Kjellin furnace is in reality a large transformer, in which an alternating current of low amperage, but high voltage, is transformed into an alternating current



INTERIOR OF FURNACE ROOM, INTERNATIONAL ACHESON GRAPHITE COMPANY, NIAGARA FALLS, N. Y.

The nearer furnace has just been shut off and disconnected and the electrodes are lying in the foreground. The second furnace is in operation.



KJELLIN 1,000-HORSEPOWER ELECTRIC FURNACE. TOP AND BOTTOM VIEWS.

The lower shows the motors and gearing by which the furnace is tipped for pouring.

of large intensity but low pressure in the secondary coil of the apparatus. The metal is contained within an annular ring built up of refractory blocks round the primary coil of the furnace, and by varying the current in the primary, the heat developed in the secondary can be regulated as desired. The advantages of the Kjellin furnace are the development of the heat just where it is wanted, i. e., entirely within the metal, and consequent small wear and tear upon the structure and walls of the furnace, and secondly, the absence of impurities picked up from the electrodes used in all other methods of applying electric heat. The Kjellin process and furnace are being worked successfully at Gysinge in Sweden, at Gurtmellan in Switzerland, at Krupp's steel works in Germany, at Vicer's steel works in England, and also at the Araya steel works in Spain, while in America a furnace patented by Colby but worked upon the same principle has been operated with successful results at Philadelphia.

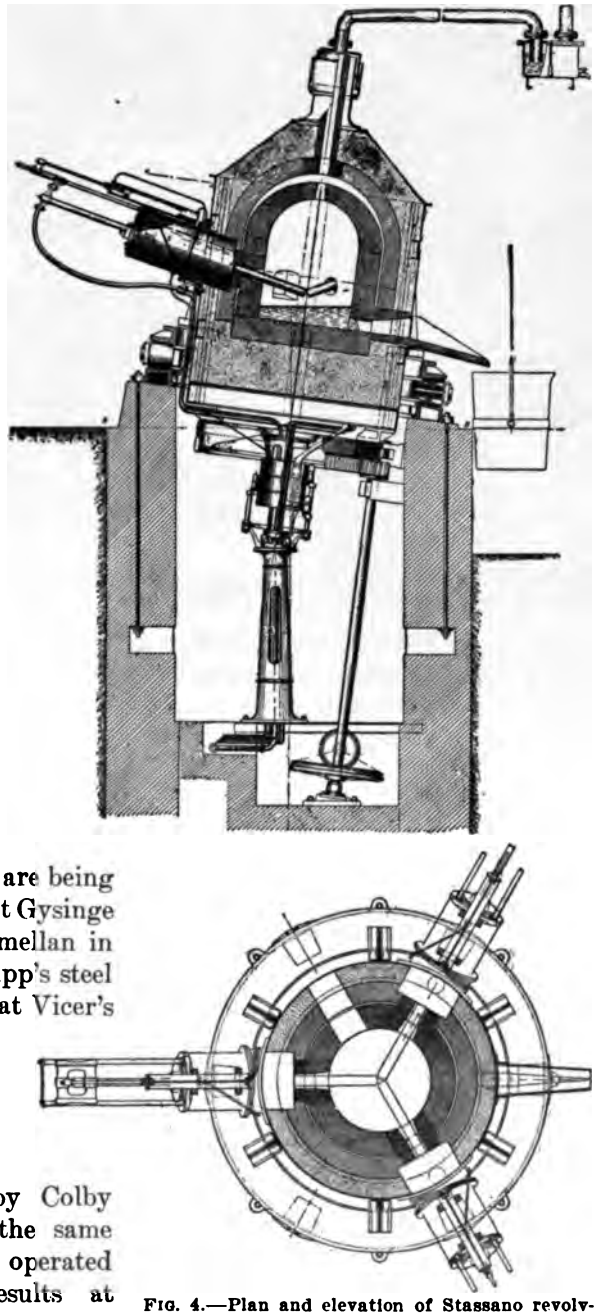


FIG. 4.—Plan and elevation of Stassano revolving furnace.

Three electric-furnace methods for the production of iron and steel

direct from the ore have been tried upon a small industrial scale in Italy, France, and Canada.

The first of these—the Stassano—has not achieved success, although large sums of money were expended upon the trials at Rome and Darfo in Northern Italy. An arc furnace of the rotary type was employed, and the ore was ground and briquetted with the lime and coke, before charging into the furnace. The costs of grinding and briquetting all the raw materials, and the difficulty of maintaining a durable lining to the furnace, were the principal causes of failure.

The Keller furnace and process for the production of gray, mottled, and white pig iron from the ore has been operated at Livet in France for several years, with moderate success. The furnaces are of 1,000-horsepower and 308-horsepower capacity, of the two-shaft type, with large carbon-block electrodes slung in chains in the center of each shaft. The heat is obtained by combined arc and resistance heating. A canal connects the hearths of the two shafts, and when filled with molten iron this canal serves as the electrical connecting link between the two portions of the furnace. The ore is crushed roughly, to a size of 2 inches, and is charged with the lime and coke into each shaft of the furnace. The electric power required per short ton of pig iron produced at Livet averages 2,300 kilowatt hours, and it is estimated that with power at $10 per electrical horsepower year a ton of pig iron could be produced by the Keller furnace and process for $11.60. A furnace designed to produce 20 tons of gray iron castings per twenty-four hours has been erected at Livet, but I am not aware whether it is yet in work.

The third process and furnace are that of Heroult, and the most important trials have been conducted at Sault Ste. Marie, Canada, under the auspices of the Canadian government. The furnace is a single-shaft furnace of most simple type. The smelting of the ore is carried out by combined arc and resistance heating, the raw materials being charged without grinding into the shaft of the furnace, in which hangs the heavy carbon-block electrode, while the sole plate primes the other electrode. The experiments with this furnace at Sault Ste. Marie proved that magnetite and titaniferous iron sand could be smelted without difficulty and that charcoal could be substituted for coke, without briquetting. The electric power required per ton of iron was 1,541 kilowatt hours, or less than at Livet, but later trials of the same furnace at Sault Ste. Marie have shown that the larger power consumption is the more correct. The furnace has now been taken over by the Lake Superior Company financing the development of this new industrial center, and 54 tons of nickel pig have been produced in it from the roasted pyrrhotite ore of the district. This attempt to found a new iron and steel center in Canada may

NEAR VIEW OF THE TOP OF A KJELLIN ELECTRIC FURNACE OF 1,000 HORSEPOWER.
The latest type, of which details have so far been kept secret.

STASSANO 1,000-HORSEPOWER ELECTRIC FURNACE, FIXED TYPE.

POURING A 1,000-HORSEPOWER STASSANO REVOLVING FURNACE.

have most important results upon the development of countries which have iron-ore deposits, but no coal with which to smelt the native ores.

Lead.—Several attempts to introduce electrolytic or electro-thermal methods for the refining of lead have been made in America, and one such process was worked for some time upon a large scale at Niagara Falls, but the company financing this venture ultimately ended in liquidation. At the present time the Betts refining process, in which lead bullion or raw lead is used as anode material, in a bath of lead fluo-silicate, is in operation at Trail, British Columbia, and at Newcastle, England. The plant at Trail was enlarged in 1906, and consists of 240 vats, each 7 feet in length by 30 inches wide. When charged, each vat contains 20 anodes and 21 cathodes, and the capacity of the plant is stated to be 90 tons of refined lead per day. The separation of the lead from the copper, bismuth, and cadmium contained as impurities in the raw lead, is reported to be almost perfect. Betts has recently proposed to introduce electro-thermal methods for smelting the lead ores, but these proposals do not appear to have yet been submitted to practical trial.

Nickel.—Nickel is produced by electrolytic or wet methods, by three companies, and at Sault St. Marie, Canada, experimental trials have recently been carried out which show that ferronickel can be successfully extracted from the ores of the district by the Heroult electric smelting furnace. A permanent installation of the Heroult furnace at this place is therefore possible. As regards the electrolytic methods of extraction, the Hoepfner process is in use by the Allegemeine Elektrometallurgische Gesellschaft of Papenburg, Germany. The process depends upon the electrolysis of mixed solutions of copper, calcium, and nickel chlorides, these being obtained by leaching the roasted nickel ore with a solution of calcium and cupric chlorides.

In America, the Orford Copper Company have recently commenced to produce electrolytic nickel, using as anode material for the vats slabs of nickel sulphide. These are obtained by operation of the " tops and bottoms " process for separating nickel and copper sulphides. The electrolyte is nickel-chloride solution, while thin sheets of pure nickel are used as cathodes. The electro-deposited nickel tests 99.5 per cent.

A third electrolytic process in use at Sault Ste. Marie is stated to be the Hybinette process (United States patent No. 805969 of 1905). The electrolyte in this process is a dilute solution of nickel sulphate, to which a small quantity of boric or phosphoric acid has been added. The anodes are made from a ferronickel-copper alloy. The cathodes are thin sheets of copper inclosed in porous bags, and held in wooden frames to prevent buckling. The flow of fresh electrolyte is directed into the bags which contain the cathodes, and by maintaining a higher

level of liquid in these, the drift of copper ions, dissolved at the anode, toward the cathode compartment is stopped, and only pure nickel is deposited at the cathode. The electrolyte becomes continuously richer in copper and iron, and is regenerated by passing over slabs of nickel or of a nickel-copper alloy. The copper is deposited and the nickel takes its place, while the iron is removed at a later stage by oxidation. The solution then contains only nickel sulphate, and is ready for use again in the vats.

Siloxicon.—This is the name given to an electric-furnace product made by Acheson at Niagara Falls, by heating carbon and silicon in a fine state of subdivision and well mixed, to a temperature slightly below that required to produce carborundum. The product is a highly refractory material, and a company has been floated in the United States for the manufacture of siloxicon crucibles, muffles, bricks, etc. The chief difficulty in the manufacture of siloxicon is the regulation of the temperature, since if this be raised too high (above 1,700° C.) the oxygen escapes and carborundum is produced.

Silicon.—F. J. Tone has produced this metal in large amount at Niagara Falls by heating sand with carbon in an electric furnace of the resistance type. It is essential that the raw materials be finely ground and well mixed, and that the temperature be carefully regulated to prevent formation of carbides. The metallic silicon must be drawn off as formed, the process being continuous, and the metal obtained bright and crystalline. Tone states that the metal may be used as a deoxidizer in the iron and steel industry and as a substitute for aluminium in the "thermit" mixture; but the demand for silicon for these and other purposes does not appear to have developed, and the difficulty at present is to find a market for the product.

Sodium.—The production of this metal by the electrolysis of the fused hydrate has grown in recent years into an important industry, and the older chemical method of manufacture has now been quite supplanted by the electrolytic method. The Castner cell and process are generally employed. Installations of this cell are now working in England, America, France, and Germany. The manufacture of metallic sodium in England is in the hands of the Castner-Kellner Alkali Company. The plant has recently been transferred from Weston Point to Wallsend-on-Tyne, where a new works has been erected, the power required being purchased from the Newcastle and District Electric Supply Company at a very low rate.

Ashcroft has patented a cell and process recently by which sodium chloride can be substituted for the hydrate in this manufacture. This process is about to be tried upon an industrial scale in Norway. Should the attempt succeed, the cost of metallic sodium, which has

TANK HOUSE AND MELTING ROOM, CONSOLIDATED MINING AND SMELTING COMPANY, TRAIL, BRITISH COLUMBIA.

Capacity, 80 tons of lead daily by the Betts process.

ELECTROLYTIC LEAD REFINERY OF THE CONSOLIDATED MINING AND SMELTING COMPANY, TRAIL, BRITISH COLUMBIA.

DOUBLE ELECTRIC FURNACE, WORKS OF KELLER, LELEUX ET CIE., LIVET.

The metal is melted in an upper furnace and poured into a lower one, in which the operation is finished.

already been reduced from 4s. to 1s. 8d. per kilogram by the improvements in the Castner electrolytic process, will be still further reduced.

The sodium produced by the electrolytic method is largely employed for the manufacture of sodium cyanide, and of sodium peroxide. "Oxone" is the trade name given to fused sodium peroxide, and this product is being advertised and sold in America for the generation of pure oxygen.

Tin.—Electrolytic or electro-thermal methods have not been applied with any success to the extraction or refining of tin, but in a branch industry—namely, "tin stripping"—they have become of considerable value and importance.

In the manufacture of cans, boxes, and vessels of all kinds from tin plate an immense amount of waste occurs with the cuttings, and the recovery of the tin from these has been carried out for some years by electrolysis. The process usually employed was first applied industrially by Goldschmidt at Essen in Germany, and consists in the use of the scrap and cuttings as anode material in a bath of sodium hydrate. Stannic-chloride solution has also been used as electrolyte in the Bergsoe process at Copenhagen. In the former case, only the tin is dissolved at the anode; in the latter case the iron is also attacked, and care is therefore required to prevent the solution of tin-chloride from becoming supersaturated with the iron salt. The chief development of the electrolytic tin-stripping industry has occurred in Germany, but similar factories have also been erected and carried on in Denmark, Austria, England, and America. The chief difficulty in working the process has been to maintain an adequate supply of tin scrap and cuttings, and some of the works have had to close down from this cause. Purely chemical methods of stripping by means of chlorine gas are also now coming into favor.

This will still further accentuate the difficulty of supplies, since the electrolytic alkali and bleach works will enter the market as purchasers of the tin scrap and cuttings. By this method of stripping, stannic chloride is produced, and not metallic tin. The manufacture of "tin salts" has already been taken up by some of the electrolytic alkali works in Europe and America.

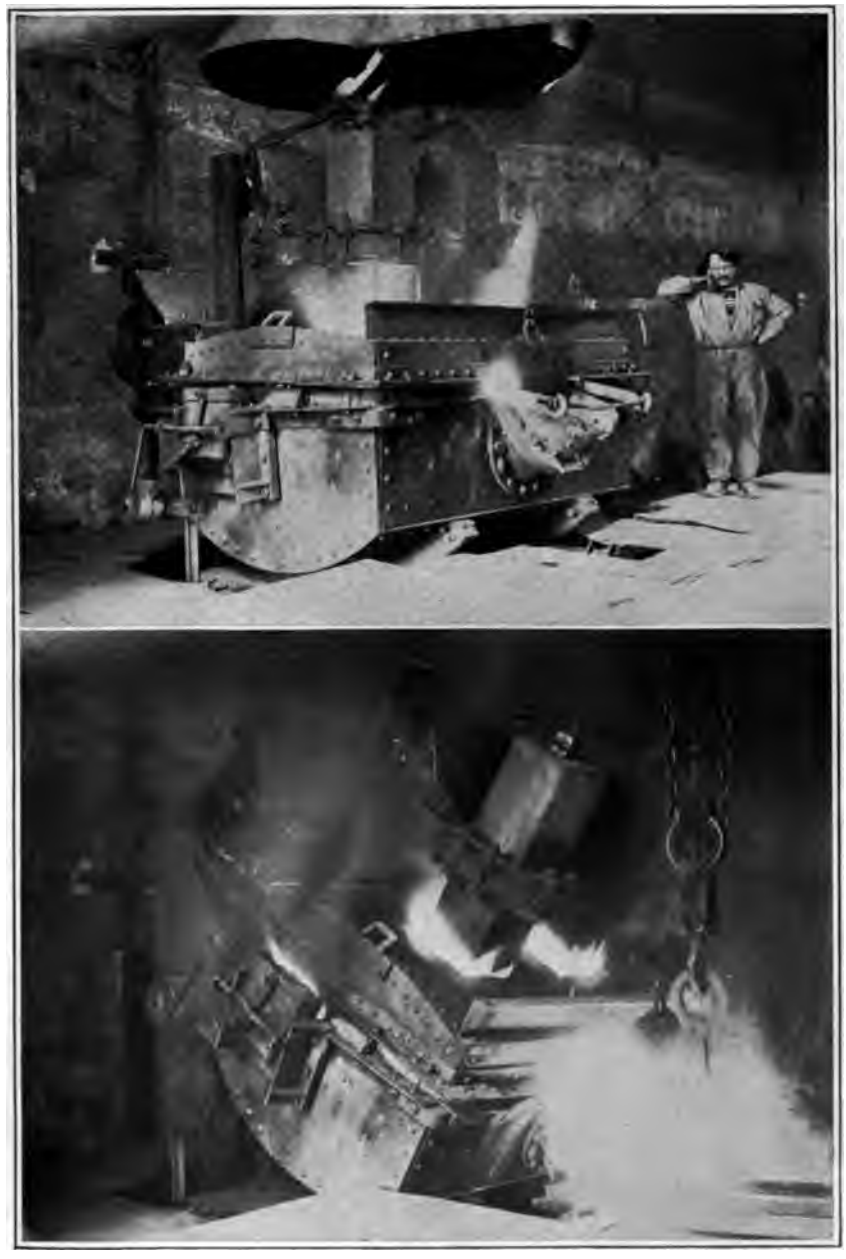
Zinc.—The attempts to apply electrolytic and electro-thermal methods in the zinc industry have met with only partial success, and the greater proportion of the zinc found in commerce is still produced by the old metallurgical method of distillation.

The coating of iron articles with a protective deposit of zinc is, however, carried on in a large number of works by the electrolytic or wet method, a solution of zinc sulphate being generally employed as electrolyte, with lead anodes. "Electro-galvanizing," as it is called, is then an important branch industry.

As regards the extraction of zinc from its ores, the Hoepfner process is in operation at Winnington in Cheshire and at Hruschau in Austria. By this process, zinc chloride is obtained from the waste liquors of the ammonia-soda process, and is electrolyzed in order to obtain metallic zinc and chlorine gas.

A zinc-ore chlorination process, patented by Swinburne and Ashcroft, is operated at Weston Point, England, by the Castner Kellner Alkali Company. Zinc-sulphide ores are treated with hot chlorine gas, and the corresponding chlorides are obtained, but the zinc chloride is sold as such, and is not subjected to electrolysis as described in the patents covering this process.

Electro-thermal methods of treating raw zinc and zinc ores are being experimented with by de Lavel and by Ferraris, in Sweden and Italy. The de Lavel furnace has already produced some hundreds of tons of pure zinc from spelter, but I understand that it has not yet been applied with success to the reduction of the ore. At Monte-Poni in Italy, Ferraris is carying out similar trials with an electric furnace, and has estimated the cost of the process at 40 lire per ton of calamine. In a recent letter he stated, however, that the method has not yet reached the industrial stage of its development.



HÉROULT ELECTRIC TIPPING FURNACE.

The lower view shows the pouring of the charge.

REPRODUCED FROM A PHOTOCHROME OF A SPECIMEN IN THE SMITHSONIAN INSTITUTION.

RECENT PROGRESS IN COLOR PHOTOGRAPHY.

By THOMAS W. SMILLIE, F. R. P. S.

For nearly a hundred years some of the ablest photographic chemists have labored to produce photographs in color.

Seebeck in 1810 obtained some results with silver chloride. Sir John Herschel in 1840 found that chloride of silver on paper after exposure to white light until it was colored violet, and then exposed to the solar spectrum, reproduced approximately the natural colors.

In the period from 1847 to 1855 E. Becquerel obtained results so remarkable with chlorides on a silver plate as to attract the attention of the whole scientific world.

Niepce de St. Victor in 1851 took up the work very earnestly, producing on silver plates treated with hypochlorite of soda not only the solar spectrum, but the various colors of flowers, fabrics, gems, peacock feathers, etc.

Hunt, Poitvin, Zencker, M. de St. Florient, Kopp, Maxwell, and others also labored in this field.

M. Carey Lea about 1882 began experimenting with the subchloride of silver and obtained beautiful results, but, like all others up to that date, he was unable to make the colors permanent.

In 1869 M. Ducos du Hauron published his heliochrome process. In this process three negatives are made, each one through a different color screen (the screens used were violet, green, and orange); these negatives were then printed on bichromatized gelatin films, colored red, blue, and yellow; the surplus color was then washed out and the films superposed.

M. Charles Cros invented a similar process about the same time.

The underlying principle of Ducos du Hauron's and Cros's processes, and indeed of all color-screen photography, may be given as follows:

If we divide the visible spectrum into three approximately equal parts we get three groups of colors, the principal tints of which are orange-red, green, and violet. Each one of these groups is complementary to the other two, and the three contain all the simple rays

which make up white light, and therefore light of any other color. If these three colors are combined, their relative intensities being kept the same, they will produce white light. If they are used as filters, however, and interposed successively in the path of a beam of light, white or colored, they will absorb it completely. But if each screen is interposed *singly* in the path of a beam of light, it will transmit all simple radiations belonging to the group of which it is the representative, and absorb all those of the other two groups. Thus if the eye were placed in the path of a beam of light, and filters of the three fundamental colors interposed one by one, the eye would receive three distinct sensations of color corresponding in each case to the portion of the original beam transmitted by the screen in question. The problem to be solved is to find a means of registering these three distinct sensations so that they can be combined and transmitted simultaneously, giving the sensation of the original beam. Ducos du Hauron and Cros accomplished this by making three negatives each with a different filter, and therefore each containing the record of the radiations belonging to its particular group in the object photographed. To combine these three records, each negative was printed on a sensitized film and the resulting print dyed the color complementary to the color of the screen with which its negative was made. Thus the film made with the negative taken with the orange screen was dyed blue, the film from the negative taken with the violet screen dyed yellow, and the film from the negative taken with the green screen dyed red. These films were then developed by washing, which removed all the emulsion covered by the dark parts of the negative, that is, the parts affected by the light transmitted through the screen in the original exposure. By superposing the three films made in this way and looking through them the object was seen reproduced in its original colors.

F. E. Ives has produced beautiful results with superposed films, but his most valuable work in color photography has been in the direction of positives on glass for the photo-chromoscope, and for lantern projections.

M. Lippmann in 1891–92 succeeded in making the first permanent direct photograph in color (afterwards improved by Lumiere). The details of this beautiful process were published in a previous Smithsonian report (1901).

Diffraction-grating color photography was invented by Prof. R. W. Wood in 1899 and published in the Philosophical Magazine, from which the following extract is taken:

> If a diffraction grating of moderate dispersion and a lens be placed in the path of a beam of light coming from a linear source, and the eye be placed in

any one of the spectra formed to the right and left of the central image, the entire surface of the grating will appear illuminated with light of a color depending on the part of the spectrum in which the eye is placed. If one part of the grating has a different spacing from the rest, the spectrum formed by this part will be placed relatively to the first, and if the eye be placed in the overlapping part of the two spectra, the corresponding portions of the grating will appear illuminated in different colors. This principle I made use of in the development of a new method for producing photographs in natural color. I have eliminated the use of pigments and colored screens entirely in the finished picture, the photograph being nothing more or less than a diffraction grating of variable spacing, the width between the lines in the different parts of the picture being such as to cause them to appear illuminated in their proper colors when viewed in the manner described.

Take three diffraction gratings of such spacing that the deviation of the red of the first is the same as that of the green of the second, and the blue of the third (the red, green, and blue in question being of the tints of the primary colors of the Young-Helmholtz theory of color vision). If these three gratings be mounted side by side in front of a lens, their spectra will overlap, and an eye placed in the proper position will see the first grating red, the second green, and the third blue. If the first and second be made to overlap, this portion will send both red and green light to the eye, and will in consequence appear yellow. If all three be made to overlap in any place, this place will send red, green, and blue light to the eye, and will appear white.

Now if three negatives are taken through red, green, and blue screens in the usual manner, and from these positives are made on albumen lantern slides, and the positives when dry are flowed with bichromated gelatin, and dried in subdued light, and the diffraction gratings of proper spacing ruled or photographed on glass are placed over these positives and exposed to the sun or electric light for thirty seconds, on washing these plates in warm water diffraction gratings of great brilliancy are formed directly on the surface of the film. Three sheets of thin glass sensitized with the bichromated gelatin are then placed under the three positives and prints taken from them. The portions of each plate on which the light has acted bears the impression of the corresponding diffraction grating, strongly or feebly impressed according to the density of the different parts of the positives. These three plates when superposed and placed in front of a lens, and illuminated by a narrow source of light, appear as a correctly colored picture when viewed with the eye placed in the proper position. Perfect registration of the different parts of the picture could not be obtained in this way, however, but if successive exposure of the same chrome-gelatin plate under the positives be made, registration being secured by marks on the plates, the desired result will be obtained. On washing this plate in warm water and drying, it becomes the finished colored photograph. Where the reds occur in the original, the spacing of the first grating is present; where the yellows occur, the spacing of both the first and second are to be found superposed; where the blues occur are the lines of the third grating, while in the white parts of the picture all three spacings are present.

Two new methods of producing photographs in color have been announced the present year, the Autochrome and the Warner Powrie processes, and although they accomplish their ends by indirect methods, they are both thoroughly practicable.

THE AUTOCHROME PROCESS.

We are indebted to the Messrs. A. and L. Lumiere for this process, which gives such beautiful results.

The process is based on the same principle applied in Cros's and Ducos du Hauron's methods, but instead of using three different screens, three negatives, and three superimposed dyed positives, one single plate serves for all these—screen, negative, and positive.

This is accomplished by the use of a mosaic of starch granules of the three fundamental colors.

The starch is sifted through very fine sieves, and the part taken which has grains of a diameter of from 10 to 12 microns. These uniform grains are divided into three portions and dyed part orange-red, part green, and part violet. They are then mixed so that the resulting powder has a grayish color and does not show the tint of any of its component parts. This powder is then spread out on glass plates which have been covered with a coat of gelatine. The single layer of spherical grains thus obtained is flattened out by pressure so that the edges of the grains touch as far as possible, the small interstices which would allow the passage of white light filled by very fine particles of carbon, and the screen thus formed covered by a thin coat of waterproof varnish for insulation and protection. Finally on top of this is applied the photographic emulsion, which of course must be panchromatic; that is, sensitive to all the light rays of the spectrum. In actual practice, it has been impossible to get an emulsion that is not slightly more sensitive to the violet end of the spectrum, so that in exposing the plates a yellow screen of a carefully chosen shade must be placed before the objective to counteract this oversensitiveness.

The plate thus prepared is exposed in an ordinary camera with the glass side toward the lens. The light rays therefore have to pass through the polychrome screen before they strike the sensitive emulsion, so that they affect the emulsion only behind the granules which transmit their particular color. Thus rays coming from a green portion of the object photographed would attack the silver salt only behind the green granules, leaving it untouched behind the red and violet. In developing after this exposure, the affected silver salt is reduced and obscures these granules, leaving the red and violet granules uncovered and transparent. As a result the plate, viewed as a transparency, after this first development shows instead of green in a green portion of the object the complementary tint, carmine red, formed by the combination of the unobscured red and violet granules. If the plate were fixed here, this is the result we should obtain. Instead of fixing, however, the plate is immersed in a bath of acid permanganate, which dissolves the reduced silver, but does not affect

the silver salt, which is still unreduced behind the granules that were impervious because of their color to the light rays which impinged upon them in the original exposure. The green granules have now become transparent because of the solution of the reduced silver which covered them. After this immersion the plate is exposed to white light for a short time and again developed. This time the red and violet are covered by an opaque layer of reduced silver from the second exposure and development.

Thus by this double exposure and inversion we get the true colors of the object from the unobscured granules, and not only this, but the effect on the eye is one of continuous and homogeneous color, as the granules are so small that rays of light from contiguous grains reach the eye confused together.

The process may be stopped at this point and the plate used as it comes from the second development, after being dried and varnished for protection. The plates are generally subjected to a process of reenforcement, however, which strengthens the colors and makes them more brilliant. If this reenforcement is carried through, the plates have to be " fixed " after the second development. This fixing weakens the tone of the colors so that the reenforcement has also this loss to make up. If the plates are not reenforced, this fixing should be omitted on account of the consequent weakening.

The illustration accompanying this article was made with the ordinary commercial Auotchrome plate, and reproduced by the halftone process.

THE WARNER-POWRIE COLOR PROCESS.

L. Ducos du Hauron in his patent of the year 1868 outlined a process of preparing a three-colored screen consisting of bands of three primary colors in juxtaposition, which screen was to be placed before the sensitive plate when making the exposure. The full importance of Ducos Du Hauron's suggestion was not recognized until Joly in England and MacDonough in America, within a very short time of each other, proceeded to apply it in practice. The Joly screens were ruled with aqueous colored inks upon a glass support coated with a thin layer of gelatine, and, although of the somewhat coarse ruling of two hundred bands per inch, were capable of producing results of considerable delicacy. The difficulty, however, both with the Joly and the MacDonough screens, lay not in the use, though this suffered from certain limitations, but in their manufacture. The mechanical operation of filling a glass plate with three series of lines of different colors without gaps or overlap was a technical problem which, in the way in which it was approached by both concerns manufacturing the screens, proved impossible of realization on a commercial scale.

The following description, however, shows that Miss Warner and Mr. Powrie have solved this problem in a very ingenious way:

The surface of a plate of ordinary glass is thoroughly cleaned and coated with a weak solution of gelatin, albumen, a mixture of the two, or of any suitable colloid body containing a proportion of alkaline bichromate. The mixture is very similar to the bichromatised fish glue employed by photo-engravers. This coating having dried, the plate is exposed under a screen ruled with opaque lines which are double the width of the transparent spaces between them. The spaces correspond, as we shall see, to the exact width of the green and red bands in the manufactured screen. Those portions of the sensitized coating which are protected by the lines of the screen are not affected by the exposure to light, but the portions underneath the spaces in the screen are rendered insoluble on exposure. "Development" takes place in warm water, the mixture of glue and albumen dissolves in the unaffected parts, and there remains on the plate an enormous number of transparent lines in relief separated by depressions which are bare glass. The plates are then immersed in a solution of a green dye which penetrates the colloid bands, and forms a screen of microscopic green lines. The plate is then placed in a bath of alum or tannic acid, which fixes the color and enables the bands to attain sufficient intensity. Emerging from this bath, the plate is washed and recoated with a sensitive mixture and again exposed under the same screen, but with an adjustment of the carrier in which it rests to such an extent that the green lines just produced are protected by the double-width lines of the negative. Between the portion of each band left uncovered and those stained green there is thus formed a narrow region which is equally protected by the opaque bands of the negative. On exposure being completed, the plate is passed as before into warm water to develop the image, and it is then seen that a screen has been formed with a series of green lines and of transparent lines in relief separated by intervals narrower than the lines in relief.

The plate is then plunged into a red dye bath and fixed and mordanted as before. Examined by transmitted light, the screen then presents a yellow color, due to the mixture of the red and green rays of the two lines which are printed at this stage. It has now to receive a third coating of bichromated mixture, and is then exposed through the back without the interposition of any negative. The light thus reaches the sensitive film through all portions of the screen not occupied by green and red lines. As soon as exposure is completed it is again developed in warm water and transferred to a blue dye bath, which stains only those portions other than the red and green, and forms with them a continuous series of colors over the whole of the screen. As a result, the screen examined under

a microscope shows a series of fine red and green lines separated by narrower blue lines, and to the naked eye examining it by transmitted light appears gray, due to the mixture of red, green, and blue.

From a practical point of view, this method, which consists essentially in leaving between the red and green lines a space which can be filled up with the blue, offers several advantages:

(1) It removes the difficulty of registration after the exposure of the screen.

(2) It avoids all possibility of white interspaces and of overlapping of two bands of different colors; and

(3) As blue is the color which appears most intense in the screen, it is an advantage that the blue lines should be slightly narrower, and thus less visible.

The screen is coated with a suitable varnish, and is then ready to receive the panchromatic emulsion.

All operations are conducted by a machine which brings the sensitive plate in contact with the screen negative, and automatically adjusts exposure to variations in the temperature and humidity of the air. Although the method is used by the originators of the Warner-Powrie process for securing screen plates in lines, yet it is equally applicable to the making of a screen plate of any form whatever, whether of regular geometrical pattern or of irregular grain.

It will be seen that by the use of these plates a negative in the complementary colors may be made by simply developing and fixing. This negative is available for making positives on glass to any number, or the picture may be developed and the negative image dissolved out, and the remaining bromide of silver exposed to light and again developed, and the result will be a positive on glass in the correct colors of the original subject.

THE STRUCTURE OF LIPPMANN HELIOCHROMES.[a]

By S. R. CAJAL.

Lippmann's heliochromes, as is well known, were founded on purely theoretical reasoning. They are interesting as a proof of the actual existence of light waves. For this reason photomicrographs of sections of the same are valuable, as proving how far the plate can register them.

It is well known that the possible registration of these waves by a photographic plate was first pointed out by Zenker, and the results have therefore been universally called Zenker's laminæ. The point is that, though theory says that these laminæ should exist, do they actually occur? Or, in other words, can one actually see them under the microscope? Obviously this is a difficult problem to solve, for we are close on the limits of microscopic resolution. Taking the case of green rays, their wave-length is 0.512 μ, a dimension which must be reduced to one-half, as the laminæ are half a wave length apart. For the spectral green, then, we have to resolve an interval of 0.237 μ (thousandths of a millimeter), which, according to Abbé's formula for central white light, $\delta=\frac{\lambda}{\alpha}$ requires a numerical aperture of over 1.40, which is the practical limit yet attained with the Zeiss apochromats.[b]

It is true that with oblique lighting we can increase the resolving power, $\delta=\frac{\lambda}{2\alpha}$ but, as Neuhauss has shown, this gives rise to diffraction phenomena, which obliterate the true lines, and may even cause reversal, as has been experienced by Senior and others. In spite of the difficulties, however, Neuhauss and Valenta alone have succeeded in obtaining excellent photomicrographs.[c] Senior's results,[d] as pointed out by Neuhauss, are far too thick, and are really diffraction

[a] Reprinted, by permission, from the color photography supplement of the British Journal of Photography, for August 2, September 6, and October 4, 1907.

[b] The objective of N. A. 1.60 with monobromonaphthaline immersion can not be used, as one dare not imbed Zenker's laminæ in this solution.

[c] When this was written (June, 1906), the author says he was unaware that Dr. Hans Lehmann had also obtained photomicrographs of sections of Lippmann heliochromes. (See "B. J.," November 30, 1906, p. 946.) Dr. W. Scheffer has also obtained photomicrographs of Lippmann plates.—EDS., "B. J."

[d] "Photography," January 3, 1902.

stripes. Hitherto only spectral rays of greater wave length have been attempted; mixed colors have not been attempted, nor have white and gray, to which most natural colors owe their luminosity, been attempted.

The examination of these points appeared extremely interesting, as it seemed possible to account for special phenomena, which mathematical calculations can not explain. Thus the disappearance of white, but not colored, portions through overexposure, the general tendency toward red or dirty yellow, the appearance of white with excessive intensification, the general shift of the colors toward the more refrangible end of the spectrum when the pictures are rubbed, the frequent want of the complementary colors by transmitted light, the appearance of black or violet on rubbing the white, the extinction of the colors, except white and black, in varnishing, and so on.

EXPERIMENTAL METHODS.

The methods employed by the author are briefly as follows:

1. The plate is soaked in water and the film scraped or stripped off with the edge of a freshly broken piece of glass. If the film is not very thin this always takes place from the glass or in that part of the film which contains no laminæ. The author also uses collodionized glass.

2. The stripped film is immersed in alcohol and water, then in absolute alcohol, and finally for a few minutes in celloidine.

3. Fine sections are cut at right angles to the film and laid in water to swell.

Sometimes the water is replaced with glycerine, and the film stained with an aniline dye insoluble in water. After some experience one may use a still simpler plan, and that is to hack the damp film along and across with a sharp scalpel, to then cover the cut places with a cover glass, and examine in this way, when one or more pieces showing the laminæ will be easily seen.

THE GRAIN OF PLATES.

Lippmann and others who work the process contend that the transparent emulsion in albumen or gelatine has no grain, or only such that as regards the wave length of light it can be neglected. Neuhauss, however, proved the existence of a grain almost invisible before exposure, but which after development varied between 0.1 and 0.3 μ. The author considers this far too high an estimate, as it would be hardly possible with such a grain to register the half-wave length of violet light ($\frac{1}{2}\lambda=0.171\ \mu$). From various experiments he believes that he is not far out in putting the size of the grain at 0.02 to 0.05 μ.[a]

[a] He speaks here of the emulsion which will register all colors up to violet. That which will only record red and yellow has a much coarser grain.

The grain is spherical, of homogeneous appearance, and of a color depending upon the duration of exposure, the hygrometric state of the atmosphere, and the developer. Generally, the grain of the less exposed parts is bluish gray; at the correctly exposed places it is of a light chestnut-brown color; when overexposed, fine greenish yellow or pale ocher-colored grains occur. Strongly solarized parts are always a clear bright yellow. It may be as well to point out that these colors are not dependent on the wave length of the light, but on the duration of the action of the latter; and they only appear on the intensified plates; the action of the mercury chloride is not only to enlarge the grain, but to give it a uniform character and opacity and a more or less gray tone. The color of the grain alters also in rainy weather.

Hitherto the grain of the developed plate has been dealt with, but, as Neuhauss pointed out, a grain can be seen before exposure, but with extreme difficulty. The author was most successful with a film deeply stained with cyanine, oblique monochromatic illumination, and a Zeiss objective of N. A. 1.40. The spotless white and transparent emulsion will keep for several days unchanged by the direct action of light, a phenomenon which proves that the grain can not suffer reduction or blackening except with the help of some photographic reducer.[a]

THE STRUCTURE OF THE PLATE IN PURE SPECTRAL COLORS.

An examination of the sections through a pure or almost pure spectrum color shows different zones; first a laminated zone and then (below) an unlaminated zone. The structure depends on the thickness of the plate, the transparency of the emulsion, and the duration of exposure. Moderately thickly coated plates show the structure for about one-third or somewhat less of the total thickness of the gelatine, and the following parts may be seen: The limiting zone, which lies between the free surface and the first lamina, the Zenker laminæ, and finally the intervals or spaces.

The limiting zone in the blue and violet is very difficult to detect because it is so thin; in the red and orange, on the other hand, it is comparatively distinct as a very fine stripe which is almost free from grain formation, but the nearer one comes to the Zenker stripes the more distinct the grain. Even in the red the examination of this zone is not easy—sections immersed in water have a refractive index so near that of water that even by oblique illumination it is almost

[a] This was first observed by Lüppo-Cramer and also by Neuhauss in 1903, therefore one can do away with the useless operation of fixing and the consequent reduction of the intervals between the laminæ. Lehmann also does not fix the plates.

impossible to see it. This is probably the reason why Neuhauss expressed doubts as to its existence. The author was enabled to see it by treating the film with an aniline dye, such as aniline blue, which is insoluble in water or by coating it with colored varnish. Under these conditions, thanks to the colored film, it can be plainly seen (fig. 1, p. 246). Its thickness in the swollen plates is about half an interval, but varies considerably, which may be caused by unequal expansion of the gelatine, and also to the varying thickness of the first lamina.

These observations confirm, at least in principle, the often-observed fact, that the surface of the gelatine forms the first interval, and that the reflecting surface of the mercury is thus in immediate contact with the gelatine during exposure.[a]

As the limiting film is only a fraction of a wave-length thick, it is easy to understand why the light reflected from the surface interferes with that from the laminæ, and why a prism is necessary or the heliochrome must be placed in a cell filled with benzole or xylol to eliminate this surface reflection.

The Zenker laminæ consist, as required by theory, of a metallic precipitate which is thicker in the middle than the sides. It must not be overlooked that in the dry plate the laminæ are very close together, and that they have great density and considerable reflective power. In the unintensified plates the color of the grains is bright brownish yellow, in the intensified gray or coffee brown.

The number of the laminæ differs considerably. In many cases it varies, as pointed out by Neuhauss, between four and six, and, depends on the intensity of the light, the duration of the exposure, and the transparency of the gelatine. Generally, the author thinks that there are more in brilliant pure colors, as in the solar spectrum, than in the mixed colors of natural objects. He has some spectra showing thirteen and more laminæ, which reach to the glass and show the colors from both sides. The same effect has been met with in some histological heliochromes.[b] There are exceptions, and as a rule the number of laminæ is only five, six, or eight.

The thickness of the laminæ is everywhere the same, as is also that of the intervals. Their intensity and the sharpness of their edges decrease the farther they are from the surface of the plate. This

[a] This fact is opposed to Rothé's assumption that the laminæ are due to the light reflected from a film of air between the mercury and the gelatine ('Compt-Rend.,' 1904, pp. 565–567). If this was so the reflection of the incident light would take place from a substance with lower refractive index than that of gelatine, therefore there must be formed a maximum and not a minimum on the surface of the gelatine. This is never the case with correctly exposed unintensified plates.

[b] Professor Cajal uses this process for obtaining heliochromes of histological and pathological sections.—Eds. "B. J."

fact, as will be seen later, is very important. Figs. 2 and 8 show that the first lamina is the most distinct, and, as a rule, more sharply defined on the edge. Then follows the first interval, which is the purest and most colorless—that is, the freest from silver—of all; then the second lamina, dense and sharply defined; then the second interval, which is almost as clean as the first. Behind these the contrasts between the laminæ and intervals are less distinct as the intervals become filled with precipitate, till the final region is reached, in which the laminæ disappear, as does also the silver precipitate (fig. 1d).

As will be seen later, the relative intensity of the first laminæ varies according to the duration of exposure and the degree of intensification. In normal plates the two first laminæ are practically the same intensity and thickness; in overexposed plates the first lamina, in consequence of photo-chemical fatigue, is weaker or disappears altogether. In this case the second or third are the strongest.

The film without laminæ varies considerably as regards thickness. In very thin plates it is almost or entirely wanting. In moderately thick plates, as in figs. 1 and 2, it may be two-thirds to one-half of the total film. As a rule it is without silver grains, though here and there some may be seen which possibly correspond to oversensitive bromide of silver. If the exposure is too long, or the plate is developed too much, this region is filled with a fine yellowish or light brown colored precipitate of coarse particles. This very frequently happens in the pure red or yellow. The appearance of the section through the other colors is, independent of the function of the wave length, practically the same. Fig. 2 shows a section through the blue at λ 0.475 μ. The extraordinary thinness of the limiting zone and the comparatively great fineness of the laminæ will be noticed. In many sections the author thinks that there are less laminæ in the blue and violet than in the more refrangible colors. It is difficult, however, to follow these fine laminæ, and it may be merely a case of coincidence (figs. 2 and 12).

THE ANALYSIS OF WHITE AND GRAY.

These are two most important colors, and from a careful consideration of all the literature on the subject and the study of many sections the author comes to the conclusion that *the formation of pure white is produced by intensification of the images.*

Without intensification—that is, without the artifical production of coarse grain—it is not possible to obtain pure whites, for these require a closely compacted, opaque film with metallic luster. As will be seen from fig. 5, the whites consist of three regions, the mirror zone, the laminated zone, and that which is characterized by diffuse reflection the rear zone.

It is characteristic for white or gray, or all colors containing an admixture of white, that the limiting zone disappears. In its place, and in place of the first lamina, there appears a new dense dark film of great metallic reflective power, 5a and 6a. This lamina, sharply defined on both sides, contains large spherical metallic grains packed close together, and of a dark brown color. The general rule is that the more brilliant the white the more opaque and compacted is this region, which, if the plate is not intensified, is only a bright transparent yellow or light brown, with distinct spaces between the grains.

This observation is important, for it proves that to obtain whites there must be (1) a metallic reflecting precipitate in the limiting zone, and (2) complete opacity of the first lamina, which combines with the limiting zone to form a morphological unit. The result is that nearly the whole of the incident light is reflected, and the few rays which do get through into the deeper parts of the plate can not produce interference. Behind the mirror zone there is a very fine interval, and a series of very dark, extremely thin, closely compacted stripes (fig. 5b). These stripes are never wanting, even if the white of the object is very pure. If the white is mixed with pink, cream, or bright blue, they are more numerous than in neutral gray. It is very significant that the distance between these laminæ is extremely small—about the same as for violet and blue; sometimes a difference in thickness and separation can be seen, as though they were caused by light of differing wave lengths. They are so fine that it is difficult to see them in a plate that is not swollen in water.

The author does not consider that these phenomena are contrary to theory. The thickness of the mirror zone on the surface of the gelatine is probably due to the combined action of the ultra-violet rays. The grain of the emulsion is too coarse to give regular periodic laminæ, but only diffuse deposit. On the other hand, the blue and violet of greater wave lengths are registered, if only partly, whilst the comparatively coarse stripes which appear between the fine ones are perhaps the maxima for the long waves green, red, and yellow for which the chromatic sensitizing is least.[a]

The preponderance of violet in the image of white depends probably on the rapidity of development. Then appears a phenomenon similar to that which is observed when a plate exposed for only a short time is exposed again for a much longer time. On development

[a] If the mirror zone is formed more easily in slow plates, this is due to the fact, already mentioned, that these plates are specially sensitive to the shorter waves. The unequal behavior of the plate with the green, red, or orange, which, unfortunately, frequently happens, is due to the addition of the same quantity of erythrosine, cyanine, and glycine red to the emulsion. The whites are then frequently not pure, but tinged with red or yellow.

only the longer-exposed picture is seen. Perhaps, also, the greater attraction of the violet maxima for the developer comes into play, and the places corresponding to red and yellow scarcely act. There appears, then, the well-known action of contrast, which is frequently observed on ordinary plates, namely, an extremely bright margin round a vigorously developed place.

From this it would appear as though the formation of white on those parts of the plate affected by light of every wave length is not due to the admixture and fusion of the reflective action of many different laminæ, as assumed by Lippmann, but exclusively to the reflective powers of a dense, opaque, dark surface film, on the opacity of which the brilliancy of the color depends. Consequently, neither the fine laminæ within the plate nor any interference phenomena (since the density of the mirror zone makes this impossible) have anything to do with the appearance of white.

That the author is correct is proved by the following phenomena:

1. If the white places are rubbed, their brilliancy decreases without color appearing; only when the mirror zone is completely removed does white disappear and blue or a more or less dark gray of violet or bluish tinge appear. In the first place there always appears a greenish blue tone, the formation of which, as shown by micrographic examination of the rubbed parts, must be ascribed to the mirror zone becoming thinner. As soon as this zone is removed there appears a dirty indefinite violet, which persists till the plate becomes quite transparent. This last fact proves that the whites are caused by the action of the violet rays.

2. Oblique illumination of Lippmann heliochromes produces, as is well known, a shift of the colors toward the more refrangible part of the spectrum. Orange-red becomes yellow, green, blue, and so on, and this shift is the more distinct the greater the angle of incidence. This change of the picture in oblique light depends on the laminated structure of the gelatine, and is easily explained by the increase of path, which the waves of shorter wave length than double the intervals must traverse. Inclination of the plate to the incident light produces no change in white, a certain proof that this color does not depend on laminar formation.

3. Neither varnishing the picture, nor slight swelling, nor testing in a benzole tank have any influence on pure white, which is thus sharply differentiated from other colors. This is also an indirect proof of the absence of the limiting zone above the mirror zone. Impure whites or grays will naturally alter in tint under a prism or oblique incident light.

EXPLANATION OF THE FIGURES.

Fig. 1. Section through pure or almost pure red. Swollen in water and examination with a Zeiss apochromat, N. A. 1.40,0 2 mm. focus. Central white light, *a* the limiting zone, *b* first Zenker lamina, *c* second interval, *d* deeper lying laminæ, with indefinite edges, *e* unlaminated zone.

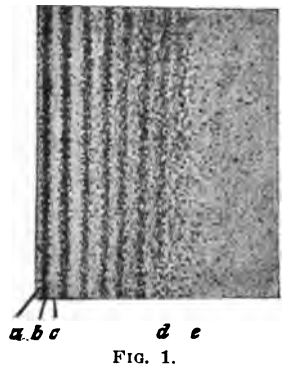


FIG. 1.

Fig. 2. Section through the blue, in the reproduction the deeper lying laminæ are badly drawn. Conditions of examination as in fig. 1.

FIG. 2.

Fig. 3. Section through the red in dry—that is, in gelatine not swollen in water. Examination in Canada balsam. Central monochromatic light.

Fig. 4. Section through greenish yellow. Same conditions as in fig. 3. The limiting zone and the grains in the individual laminæ can not be seen.

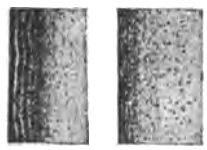


FIG. 3. FIG. 4.

Fig. 5. Section through pure brilliant white. Swollen gelatine, *a* opaque mirror zone, *b* the fine stripes lying under the mirror zone.

Fig. 6. Section through yellowish white, *a* mirror zone, *c* fine stripes, *d* laminæ corresponding to the yellow.

Figs. 7, 8, and 9. The action of intensification on the color.

Fig. 7 shows the unintensified color, the stripes are too dark in the reproduction.

Fig. 8. The same color intensified once in a sublimate bath.

Fig. 9. After two intensifications. It will be observed how the scarcely visible grain in fig. 7 becomes thick and dark in fig. 9.

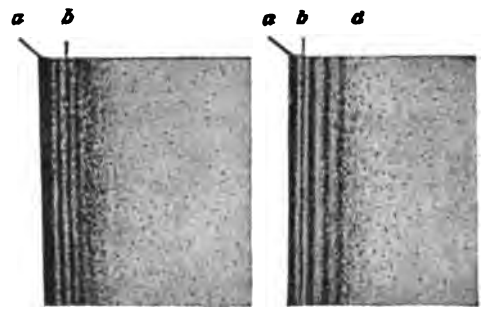


FIG. 5. FIG. 6.

Fig. 10. Red. The thickness of the first laminæ was reduced by friction, so that blue and green stripes appear.

Fig. 11. Section through bright green, which by overexposure and overdevelopment has become white; *b* mirror zone, *c* fine stripes belong to the white; the other laminæ *belong to the green.*

Fig. 12. Section through overexposed blue. The paleness of the laminæ *e* and the absence of the mirror zone will be noticed.

Fig. 13. Section through overexposed orange. The first lamina *f* is wanting, and the second is also rather pale.

Fig. 14. Section through bright blue mixed with white; *a* mirror zone, *b* fine secondary laminæ.

Fig. 15. Section through bright lemon yellow. The first laminæ represent the phase of conversion into the mirror zone.

Fig. 16. Section through underexposed and overdeveloped green, which corresponds to the shadow side of an orange. The fineness and transparency of the laminæ, which are somewhat too dark in the reproduction, will be noted.

Fig. 17. Section through the blue in a plate exposed without a mercury mirror.

FIG. 7.

FIG. 8.

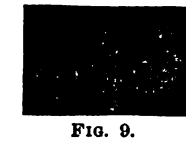


FIG. 9.

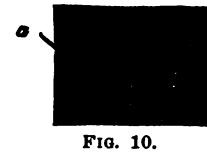


FIG. 10.

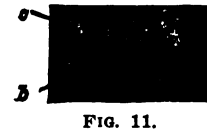


FIG. 11.

FIG. 12.

FIG. 13.

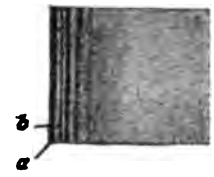


FIG. 14.

FIG. 15.

FIG. 16.

FIG. 17.

COLORS MIXED WITH WHITE.

Compound tones, such as gray, pink, cream, light blue, etc., formed by admixture of a principal color with white, occur very frequently, and the artistic value of the reproduction depends to a great extent on the correctness of the tonality of the latter. One may assume *à priori* that the compound colors possess a better mirror zone, which gives the white, and secondly laminæ with intervals corresponding to the principal color. This actually is the case, and proof is afforded in the section of a yellowish white (fig. 6). The surface of the plate shows the thin transparent mirror zone. Close behind is a fine pale stripe (*c*), which perhaps belongs to the violet or blue, and then two or three thick lines separated from one another by wide intervals which correspond to the laminæ of the yellow.

Irregularities in the intervals between the laminæ are frequently observed with compound colors; sometimes they are due to illusion and to unequal absorption of water. In those cases in which the water has acted for

a long time and the finer lines are nearer to the surface, the different thickness and distance of the laminæ must be ascribed to the registration of different waves. Neither with compound colors nor pure white are all spectrum waves to be distinguished.

Bluish, reddish, and greenish white have a similar structure; all these colors show with the mirror zone a laminar system and their optical effect is added to the reflection from the mirror zone.

For the chromatic interference, as with pure colors, only the two first—or, as noted above, in the case of a fine secondary strip (fig. 11c) the three first laminæ—are used. The color thus formed is weakened by the somewhat disturbing reflection of white from the mirror zone. That the surface film, in spite of its paucity in precipitate, causes weakening of the color is proved by rubbing or scraping the plate, for then the whitish tinge disappears and the dominant color appears much more strongly, and if the scraping is continued it is shifted toward the more refrangible end.

After the author's views as above had been published, he heard of Lehmann's work on the same subject, but the results of the two workers are not in agreement.

According to Lehmann, white is formed not, as assumed by Lippmann, by the confusion of the incident light of various vibrations from the laminæ, but by reflection from two laminæ corresponding to complementary colors. As proof of this assumption, Lehmann advances (1) the possibility of obtaining photo-micrographs under special experimental conditions of the registration of two synchronous waves; (2) the spectroscopic examination of the light reflected from the whites of a picture placed in a benzole tank. In the latter case he observed that the whites of the picture did not, as the whites in nature, emit a continuous spectrum, but a discontinuous one, or a continuous spectrum with two or three distinct maxima preponderating. From this Lehmann concludes, in agreement also with Pfaundler,[a] that the plates do not possess the power of registering simultaneously a greater number of waves of varying vibration, but only two or three, and he explains the formation of white and gray by the well-known property of the retina of synthesizing to white when two complementary colors act on the rods.

In principle this coincides with the author's conclusions as to the formation of two kinds of laminæ; but the question does not appear to the author to be experimentally proved, for, as will be seen later, the deeper lying laminæ do not, or only in rare cases, help to produce the colors.

Lehmann's conclusions have caused the author to repeat his experiments, and he comes to the conclusion that brillant whites are due

[a] *Drude's Annalen*, 1904. See also "B. J.," October 12, 1906, p. 807.

entirely to the first mirror zone and not to laminæ. The following are also advanced in favor of the author's views, and much against Lehmann's:

a. If the whites are rubbed with a pad dipped in alcohol till the mirror zone disappears, there appears first blue violet, although the opacity of the metallic particles is appreciably reduced when examined by transmitted light. If the picture is still further rubbed till quite transparent, the white never appears when it is put in the benzole tank. The colors behave quite differently as they reappear.

b. If a very thin plate is used so as to prevent the formation of the unlaminated zone, all the *colors* will be visible when the plate is looked at from the back, but *white* is never seen.

c. If a plate is left, without varnishing, exposed to the air for some months, the whites are the first to disappear, probably on account of oxidization. This rapid alteration can be explained by the fact that the mirror zone, as already pointed out, lies absolutely on the surface of the gelatin.

d. Everything which attacks the surface of the gelatin of the developed plate, such as washing, friction, deposition of mercury oxide on the sensitive film, etc., prevents the appearance of the whites, whether the plate is examined in air or benzole.

e. In underexposed plates, if no color of the longer wave lengths green, yellow, and red has acted, nothing but a brilliant white is obtained on intensification, especially if slow-acting plates are used. On the assumption that two complementary colors, for instance, red and green or yellow and violet, have been registered, this formation of white is incomprehensible.

f. Whites also appear on plates which have been exposed without the mercury mirror, and in which the laminæ are extremely thin. The white obtained by intensification is as brilliant as in pictures obtained under the ordinary conditions.

g. White is also obtained by the intensification of pictures taken on nonorthochromatized plates.

h. The examination of white in oblique light, that is, under the glass prism, shows, as already mentioned, not the least qualitative change, whilst all other colors are shifted toward the greenish blue. It should also be noted that whilst red, in passing into blue-green, misses the orange-red, yellow, and bright green, the blue only slightly shifts toward the violet. The result, which can be easily explained mathematically, is not in favor of Lehmann's theory. If the white is actually formed by the action of two reflecting laminæ belonging to two complementary colors, as, for instance, red and green, it is not obvious why, in the shift of the red into blue-green and the green into dark blue, that is in the shift into two colors which are no longer

complementaries, the white does not shift into a more or less distinct blue, and therefore disappear as white.

i. Later experiments on thin sections have proved that the fine lines at equal distances which belong to the whites do not as a rule exceed three, and that, apart from the transparent intervals behind the mirror zone, the spaces between the laminæ are filled with a diffuse precipitate. Under these conditions the interference action of such laminæ must be nil, even if the incident light reaches them.

k. Finally, spectroscopic examination of the pure whites shows a continuous image without gaps, which is more or less similar to the continuous spectrum from a white object. What is the difference, asks the author, between his and Lehmann's spectral examination?

The author thinks that Lehmann did not test pure brilliant whites, as obtained by intensification on slow, fine-grained plates, but the half-white with a bluish or violet tinge, which usually appears in fast plates without intensification.[a] This pseudo-white, when examined in the benzole tank, appears somewhat better, but can never be compared with the white obtained by Lippmann, Neuhauss, and the author under the stated conditions—that is, treatment with sublimate and an amidol developer after weak development. This assumption appears to be all the more likely as the author's spectroscopic examination of the dirty gray on quick plates without intensification, as in Kranseder's plates, made according to Lehmann's formula,[b] shows that the spectrum actually does possess maxima.

The author was never able to obtain satisfactory colors before he learned how to intensify, but since then he has obtained whites, in all sorts of subjects, which are purer and more vigorous than in the best black and white photograph.

ANALYSIS OF THE GRAY AND DARK PARTS.

The dark tones, or those mixed with black, are dependent, according to theory, on the fineness and transparency of the laminæ. If, for instance, we examine a dark green, as in fig. 16, we shall see that the mirror is quite absent, and that in its place is a colorless plane. Noteworthy also is the small number of laminæ, only four or five, and especially their extraordinary transparency and light yellow color. In many cases the laminæ appear to consist of a single row of yellowish grains. The intervals are clean, comparatively large, and quite free from precipitate. Under such conditions it is obvious

[a] As a matter of fact Lehmann states in his book that he never intensifies.

[b] The author's experiments with Lehmann's plates with the special filter have given excellent results as regards speed and color rendering. All attempts to obtain a good white were failures. Further, the colors are somewhat dead-*looking.*

that the plate will reflect only a small part of the incident light and also allow the dark background of the asphalt on the back of the plate to shine through. Naturally, the color will be much darker the paler the laminæ. Dark colors also appear very stable when the plate is rubbed, a fact which is easily understood when one bears in mind the extraordinary transparency of the laminæ which take part in the interference.

BRILLIANCY AND PURITY OF THE INTERFERENCE COLORS.

Everyone who has worked at all with the Lippmann process will have observed the great differences in the purity and brilliancy of the colors. Some very transparent plates reproduce the whole of the spectrum in brillant pure tones; other emulsions give all the colors, but dead and impure; others again as though covered with a gray or white fog. Some fairly sensitive plates, which give otherwise good colors, convert the white into gray, violet, or cream; others again give certain colors, usually red, orange, and yellow, fairly well, but are totally wanting in green, blue, and violet.

In order to understand these phenomena one must bear in mind that Zenker's exact theory is only carried out under defective conditions, due chiefly to the special nature of the photochemical actions. The laminæ are not absolutely smooth and sharply defined, nor are they everywhere of equal thickness, also they do not possess that uniform perfect transparency which theory requires, so that all may take part in the interference of the incident white light.

The brilliancy and intensity of the interference colors depends, at least so it is generally assumed, on the perfection of the lamellar structure of the plate, and the purity and brilliancy of the colors is greater the greater the number of the reflecting laminæ. Broadly this view is correct, but theory does not coincide with practice. The author states that many of his pictures of great brilliancy and truth possess only three or four especially brilliant and correct reflecting laminæ, whilst others with ten or twelve regular distinct laminæ gave less bright pictures. The brilliancy of the colors thus depends not on the quantity, but the quality of the laminæ and intervals.

From some hundreds of very careful observations the author comes to the conclusion that in most cases the color is due to the reflection and interference of light from the two uppermost laminæ. The deeper-lying ones have very little to do with the formation of the colors; in the first place because they receive but little light, and therefore can only reflect little; secondly, because they have not sharp limits and are not separated by perfectly colorless intervals, so that the light can not be properly analyzed, but only diffused; and

thirdly, because by development and intensification the two upper films far surpass the others in reflective power.

The most important experiments which support these views are simple and easy to interpret.

1. As already noted, and as Neuhauss states, rubbing the dry plate with a pad dipped in absolute alcohol causes the colors to shift toward the violet. The red becomes orange-red, then yellow, then green, and finally blue and violet, and these colors persist for an unlimited time in the dry plate, or if it is immersed in a benzole tank. This is explained by the erosion of the first lamina. If the friction is continued the violet disappears and the original color appears. This will occur once or twice, but it is then so dark and dead that its action on the tint of the underlying part of the plate is almost nil. Friction beyond the fourth lamina produces complete disappearance of the original color. Friction is therefore an excellent method of studying the functional action of individual zones.

The above phenomena are quite clear on the assumption that only the first two laminæ, or perhaps also the third after intensification, take part in the formation of the color. As a matter of fact, rubbing with alcohol very slowly reduces the thickness of the first lamina, so that the distance between its surface and that of the second lamina is reduced, and therefore it has all values between the half wave length of the original color and violet. If the first lamina is completely removed the surface of the gelatin is formed by any plane which is parallel to the first lamina. In this case the distance between the two reflecting planes, that of the surface of the plate and the second lamina, already smaller than the half wave length of the violet, and therefore no color can be produced. If the third lamina is not sharply defined and does not possess sufficient reflective power, color definitely disappears. In certain cases, however, the third and even the fourth lamina are effective, and then we have the original color, but very dark and dead. Thus the color of an orange, after it has disappeared through removal of the first lamina, appears, through interference between the second and third films, brownish or dark orange, when examined in the benzole tank.

2. The correctness of these views is shown by an examination of thin sections obtained by hacking the gelatin crisscross fashion with a scalpel. Treated thus, a red which had shifted into green showed that the first lamina only had become thinner; the appearance of the blue was coincident with its almost complete disappearance, and the reappearance of the red, assuming that the second and third laminæ were not damaged, took place when the friction was continued to the second interval. The original color finally disappeared with the destruction of the second lamina.

3. As already stated, the brilliancy of the color is independent of the thickness of the plate and number of the lamina. Very brilliant colors are seen in quite thin plates of 4 to 5 pr. thickness.

This refers mostly to colored objects, in which there are usually compound colors. With spectra photo-micrographs of anatomical preparations or, briefly, when pure or almost pure waves act on the plate, the deep lying laminæ are almost as well formed as the surface ones. Naturally in such cases friction only destroys the colors with the fourth or fifth lamina.

ANALYSIS OF WHITE PLATES CAUSED BY EXCESSIVE INTENSIFICATION.

The above results of the author's researches on the whites elucidate a phenomenon which is often observed before or after fixation, when a plate is intensified with perchloride and amidol, plus sulphite.

It has already been stated that the grains become larger, and, therefore, closer together. Consequently, the reflective power, particularly of the first lamina, which is most easily attacked by the reagents, is increased.

So long as the grains of the first metallic film possess a certain transparency the color does not markedly alter, as part of the incident light reaches the second lamina and is reflected back. If, however, as is generally the case with a second intensification, the first film loses its transparency almost entirely, then the ratio of reflective power of the first two films is altered, as that of the first preponderates. The result of this is that the color presents a dirty white appearance, and the want of transparency is greater the thicker the grains of the first lamina become. With great intensification the colors completely disappear, especially in the fully exposed parts, and the picture appears as though covered with a milky fog.

Figs. 7, 8, and 9 show the appearance of a section through almost pure green before and after intensification. Before intensification the laminæ are pale and fine-grained, and the metallic precipitate is absolutely wanting on the surface (fig. 7). Therefore the light can penetrate to the second and third film, and their analytical and reflective actions are added together. It is quite different in fig. 9, which is a section through the same color after two intensifications. All films, especially the first, act like a white-producing mirror—that is to say, they contain extraordinarily coarse grains and have lost the best part of their transparency. Moreover, it can be seen that each film has become distinctly thicker. The limiting zone has given way to the mirrror zone. Fig. 8 shows the same color with one intensification.

The practical result of these researches leads one to formulate the rule that Lippmann photochromes should be intensified once to give

good whites, but should never be intensified twice, as otherwise the first lamina will be converted into an opaque mirrorlike film, and therefore the chromatic interference which is specially produced by the second lamina can not longer take place.

ANALYSIS OF OVEREXPOSED PLATES.

Even by mere examination an overexposed picture shows a lusterless white, grayish or pinky, and more or less pure, but hard-silhouetted colors. Microscopic analysis explains this phenomenon, which is one of the most frequent defects in working Lippmann's process.

The laminæ of such plates consist of a thin yellowish and extraordinarily pale precipitate, which allows more light to pass to the underlying films than usual. The intervals also are more or less strongly acted upon; they show a delicate, light gray grain formation, so that the contrast between the laminæ and intervals is considerably decreased (fig. 13). Finally, the first lamina is completely wanting or reduced to a pale indefinite stripe (figs. 12 and 13). This paleness is more or less seen in the second lamina. The phenomenon naturally depends on the fatigue of the surface region of the sensitive film, which is so strongly solarized that it can not be reduced to a dark color.

Whites show in overexposed plates a very pale and transparent mirror film, which with considerable solarization may even be totally absent. The pale, small, yellowish and almost invisible grains possess no reflective power. Behind the mirror zone are various fine stripes without contrast, and an extended region of irregular and comparatively vigorous reduction which extends to the glass.

CHANGE OF COLOR BY OVERDEVELOPMENT INTENSIFICATION.

The least overstepping of the correct exposure leads, as will be seen later, to falsification of the colors and loss of the whites. Red and orange are exceptions, the two colors which from their poor photochemical action rather gain than lose with moderate overexposure.

The color value of the picture is also changed by overdevelopment or intensification, even if the plates are correctly or slightly underexposed. If the damage is not too great it can be equalized by cementing under a prism with Canada balsam, as then the gelatin loses a little water, and therefore the laminæ get nearer one another. If the fault exceeds certain limits, the colors are so falsified that neither in moderately oblique light nor in a benzole tank will the picture give the true colors.

Microscopic analysis shows that such color changes are to be ascribed to a thickening of the first lamina, which then reaches the *surface of the* gelatin. Since by this thickening the difference in

the path of the rays reflected from the surface and from the interior of the plate is enlarged, the same wave length, even with normal, or almost normal, illumination, which produce the laminæ, will not predominate, as will light of a greater wave length.

One of the most unpleasant and most frequent occurrences in Lippmann's process is the transition of the blue and violet into white. This change is due, not to a narrowing of the intervals, but only and alone to their lessened transparency, and especially that of the first, which then acts as an opaque screen. It is thus quite immaterial that the laminæ and the deeper-lying ones are sharply defined, or that the top one remains intact, the waves of light can not actually penetrate to the lower laminæ, and therefore can not produce interference. In plates examined without a prism and without the benzole tank, this trouble often appears if the blue shows well, because the limiting zone, as is easily seen, is the more troublesome the shorter the wave length of the light.

If the tank does not remedy this fault, one can reduce the plate so as to enable the light to penetrate into the depths of the film. As a preventive the use of light screens has been suggested to reduce the energetic action of the shorter spectral waves. Such screens have been used by all experimenters, and especially by Neuhauss and Lehmann, with good results. The author uses a weak solution of aniline yellow with some erythrosine in collodion on the back of the plate; the use of the screen, which is rather expensive, is thus avoided. Also a screen absorbs a great deal of light, and if not of first-rate quality detracts from the purity of the pictures.

FALSIFICATION OF THE COLORS THROUGH DAMPNESS OF THE PLATES.

Similar falsifications of the colors appear in the use of too dry plates in damp weather. The correctly obtained and fixed laminæ become considerably farther apart by absorption of atmospheric moisture, and the oft-noted fault of a shift of the colors toward the red is seen, and green becomes yellow, and yellow orange or red, and so on. In order to obviate this fault the plate should be brought into hygrometric equilibrium with the air. A somewhat dangerous remedy is reducing the grain of the laminæ with a reducer.[a]

[a] The reducers and especially dilute potassium cyanide solution, when carefully used, restore the colors of overdeveloped or damp plates. But not only do the whites suffer severely, but after some time the grain bleaches very much, and the picture becomes worse. The author has therefore entirely given up the use of reducers. Only in individual cases does he use it locally to restore the blues and violets. This retouching is done on the wet plate with a fine brush dipped in weak potassium cyanide solution.

The reverse phenomenon appears when the plates are placed in the benzole tank or mounted with a prism. The change of color thus induced is toward the more refrangible end of the spectrum, and sometimes produces the shift of more than half a tone. For instance, the red becomes orange red, and orange yellowish. Blue and violet, on the other hand, are scarcely modified, or, rather gain, in power and purity.

This well known phenomenon is based according to the author on the giving up of water by the gelatine to the benzole or to the Canada balsam, so that naturally the distance between the laminæ is decreased. In order to get over this difficulty development should be rather longer, so that the colors shift toward the red, or, still better, the plate should be warmed before exposure, and just before placing in the mercury slide, in a drying cupboard at 86° F.

FALSIFICATIONS OF THE COLOR TONES IN THE DARKER PARTS OF THE PLATE.

With underexposed plates or in places which correspond to the shadows of a colored object, the pitcture shows, instead of the true color rendering, another color, and, as a rule, it is the opposite to the phenomena observed with overexposed plates, the shift being toward the more refrangible end of the spectrum.

Thus the shadows of a head in sunlight are brownish-green or greenish-yellow, instead of the delicate rosy tint. An orange which is correctly reproduced on the illuminated side shows pure green in the shadows (fig. 16).

These and other imperfections of dark or only briefly exposed objects can be ascribed, according to the author's researches, chiefly to fixation, the action of hypo or cyanide. Keeping to the example of the orange, the plate was, as a matter of fact, affected in the bright and dark parts by rays of different intensity, reflections from neighboring objects being excluded, but in the strongly exposed parts there were formed numerous dense laminæ, while in the shadows these were fine and pale; in many cases there were only formed a small series of yellowish grains.

The cause of this phenomenon, which had already been observed by O. Cramer, is that in fixation there is more silver bromide dissolved out in the shadows the weaker the action of light, and therefore thin laminæ in the dark parts approach one another during drying; while in the brightly lit parts, which are therefore poorer in silver bromide, they scarcely alter their relative positions.

From this fact we may deduce the practical lesson that Lippmann plates should not be fixed, because the disappearance of the silver bromide causes a general reduction of the intervals and a consequent *falsification* of the colors.

According to the author's views complete fixation of the pictures, even when all other operations, such as exposure, development, intensification, etc., have proceeded normally, causes with normal, or almost normal, illumination at least, a slight shift in the direction of the more refrangible end of the spectrum, a fault which can not be remedied, as mounting under a prism would only slightly increase the shift; and if this failure has been less frequently observed than the opposite one (that is, too great a distance between the laminæ), it is due to vigorous intensification, which compensates, to a certain extent, the contraction of the intervals between the laminæ, actually by thickening the first one.

It is obvious from the researches that the most frequent imperfections of Lippmann heliochromes is due to the almost unavoidable changes of the normal distance between the laminæ, a change caused by the mechanism of the photographic operations. Under certain conditions—complete fixation, too short exposure, too short development, etc.—the laminæ are too near one another, and the colors shift toward the blue. In other and much less frequently occurring failures the laminæ become thicker, the reflecting surfaces are farther separated from one another, and the colors are then shifted toward the red.

ANALYSIS OF PICTURES WITH MATT FAINT COLORS.

Many emulsions, in spite of great transparency, show a tendency to give only matt colors, and actually do not give white. A microscopical examination of such plates proves that the cause of this phenomenon is due to too little contrast between the laminæ and the intervals. The former are formed in sufficient number, but from their yellowish or bright greenish-gray color are not sufficiently differentiated from the more or less gray intervals. The mirror zone which reproduces the white is very pale and transparent, and possesses no reflective power.

In order to obviate this very frequent fault, which unfortunately occurs with every third or fourth emulsion, the author has made many experiments and obtained successful results by alteration of the developer. To increase the contrasts between the laminæ and the intervals the following should be used:

	ccs.
Potass. bromide, 10 per cent sol	20
Ammonia	1–1.5
Pyro, 1 per cent sol	15
Water	250

and the general rule is: Reduction phenomena appear very quickly in the intervals with an excess of ammonia, while the opacity of the laminæ is increased by an excess of bromide and pyro; but the laminæ ought not to be so opaque as to prevent the intensifying action of the *deeper lying ones.*

LAMINÆ IN PLATES EXPOSED WITHOUT A MERCURY MIRROR.

The earlier experiments of Krone and the more recent ones of Rothé have proved the possibility of obtaining interference colors with Lippmann's plates without using a mercury mirror. The pictures thus made have only a faint brilliance, and require, moreover, much longer exposures. This is obvious, as the stationary waves are formed by interference between the incident light and the few light waves which are reflected from the surface between the gelatin and the air. The author has repeated the interesting experiment and obtained comparatively good results of the shorter wave lengths, violet to green; far less satisfactory, however, were the reproductions of the red, orange, and yellow. Examination of sections shows in all cases the presence of correct laminæ, which are few in number, however, and are separated by intervals which are not free from precipitate. Fig. 17 shows the section through the blue of such a result. The laminæ, only three or four in all, are composed of very fine grains. The second lamina is the best and darkest. In the limiting zone there is no precipitate, and this proves therefore that, as with the mercury mirror, the surface of the gelatin is identical with the first opposite phase plane.

The whites obtained in this way are also the same as those obtained with Lippmann's method; behind the dense thin mirror zone there are some fine laminæ, which, deeper down, degenerate into an irregular gray deposit.

CONCLUSIONS.

From his long and comprehensive researches on the structure of the Lippmann heliochromes the author comes to the following conclusions:

1. As already recognized by Neuhauss, the spectrum colors are produced by a series of metallic laminæ, separated from one another by colorless intervals. These films occupy a third or a half of the thickness of the gelatin. Near the free surface they are sharply defined and distinctly separate one from the other, the deeper they are the more diffuse and indistinct they become.

2. Between the first laminæ and the surface there is generally a clear zone, which corresponds to the first opposite phase or null point. Frequently through intensification this contracts considerably, or completely disappears.

3. The colors of natural objects give pictures the structure of which agrees generally with that of the spectral colors.

4. The production of white is due to the formation of a dense metallic lamina, the mirror zone, with great reflective power, and *composed of an* opaque dark closely compacted precipitate. Then

there are some fine closely contiguous stripes, which probably correspond to the short waves of the visible spectrum.

5. The colors mixed with white show with their own laminæ a thin surface film, filled with a metallic precipitate, the mirror zone.

6. In certain cases colors mixed with white show two kinds of laminæ, large stripes far removed from one another, which belong to the long waves of the predominant color, and one of two fine pale films corresponding to the shorter wave lengths.

7. The interference phenomena, through which the colors are produced in Lippmann heliochromes, can be ascribed actually to the action of the rays reflected from the first and second laminæ. The others have only a faint, but, to a certain extent, an intensifying action. Pure spectral colors are an exception in their formation; if the metallic precipitate is quite transparent, the deeper lying tones may also act.

8. The good rendering of the colors is principally caused by the correct limiting and perfect transparency of the upper laminæ, as well as the normal value of the intervals. All causes, such as long exposure, overdevelopment, incorrect intensification, etc., which upset the ratio of the two first laminæ as regards intensity and thickness, or such things as fixation and damp, which affect the size of the intervals, alter the true colors and cause false tonalties. From this it is obvious that the greatest difficulties of the Lippmann process are as follows: *a*, the distance of the individual laminæ produced in the plate by the colored light during the exposure must be strictly kept, in spite of the contracting action of fixation and the expanding action of intensification; *b*, too little transparency and too great thickness of the first lamina must be avoided, although a certain opacity is esential for the correct reproduction of the bright tones. By careful, clean work the perfect balance of these two opposite requirements must be fulfilled by workers in interferential photography.

BRONZE IN SOUTH AMERICA BEFORE THE ARRIVAL OF EUROPEANS.[a]

By ADRIEN DE MORTILLET,
Honorary President of the Société Préhistorique de France.

Long before the discovery of the New World the Indians living along the Cordillera of the Andes, from Chile to the Caribbean Sea, already knew how to extract and work various metals.

For a long time we have been sure of the presence among these metals of gold, silver, and copper, but we have been much less certain with regard to the use of bronze.

In spite of oft-repeated assertions, we have until recently continued to entertain doubts as to the use of an actual alloy of copper and tin in South America before the European conquest. These doubts, inspired by a very reasonable conservatism, were founded principally on the lack of exact data in regard to the composition of the metal from which the objects collected by archæologists were made and on the want of positive evidence as to the existence in those regions of very rich tin-bearing deposits, which are to-day actively exploited. Only through chemical analyses, with their guaranties of accuracy, could a definite settlement of the question be reached.

It is the results of some analyses of this sort, recently made and partly unpublished, that I present here. These analyses, fifty in number and dealing with specimens as different in their nature as in their origin, furnish us with decisive proofs regarding an important part of the South American continent.

A first series (Nos. 1 to 26) was intrusted to MM. Morin frères, assayers of the Bank of France. It includes objects collected along the course of the Mission of Créqui-Montfort and Sénéchal de la

[a] Translation, by permission, of paper presented at the Premier Congres Préhistorique de France, Session de Perigueux, 1905.

Grange, from the following localities: First, the ancient ruins of Tiahuanaco near Lake Titicaca, north of the high Bolivian plateau; second, from very old cemeteries which have been explored, in the vicinity of Yura, between Uyuni and Potosi; third, from the Republic of Ecuador; and fourth from several localities north of the Argentine Republic, between Salta and the Bolivian frontier. In a second series (Nos. 27 to 48) have been grouped twenty-four analyses taken from the interesting work of Juan B. Ambrosetti upon bronze in the Calchaqui region. These analyses were made by Messrs. Juan J. J. Kyle, chemist of the mint of Buenos Aires, Eduardo Suarez, and Herrero Ducloux. They relate entirely to objects discovered in the valleys along the eastern side of the Cordillera, northwest of the Argentine Republic (provinces of San Juan, of La Rioja, of Catamarca, of Salta, and of Jujuy).

NATURE OF THE OBJECTS ANALYZED.

1 2 3 4 5 6

A. Bolts in the form of a double T, used to bind the stones in the walls of the tumulus of Acapana, Tiahuanaco. (Fig. 1.)

B. Knives with perpendicular tangs in the center of their blades. (Fig. 2.)

C. Circular pieces made of thin sheets of metal and pierced with holes for suspension.

D. Pins with large, flat heads. (Fig. 3.)

E. Flat, thin axes, with slight shoulders. (Fig. 4.)

F. Heavy, thick axes, with prominent lateral shoulders, in the shape of a T. (Fig. 5.)

G. Bells shaped like the flattened body of a cone.

H. Metal rods with one end sharpened.

I. Small, heavy, molded sphere, with a stationary ring on the inside.

J. Open bracelet of a strip of metal.

K. Axe with large thick tang pierced with a hole. (Fig. 6.)

L. Molded, circular pieces, one face decorated with designs in relief and the other furnished with two suspension rings.

M. Small disk with appendage pierced with a hole for suspension.

Objects Analyzed.

Number.	Region.	Objects.	Copper.	Tin.	Lead.	Zinc.	Antimony.	Bismuth.	Nickel.	Silver.	Iron.	Arsenic.	Sulphur.
	BOLIVIA.												
1	Tiahuanaco	Bolt (A)	98.64								0.43		0.87
2	id	id	95.65		0.12		Traces.				1.68		2.55
3	id	Knife (B)	93.10	5.83	0.63		0.06				0.36		
4	id	Disk (C)	93.76	6.02	Traces.		0.06				0.13		
5	id	Knife (B)	92.80	6.71	0.17		0.06				0.21		
6	id	Pin (D)	91.41	7.70	0.30		0.11				0.41		
7	Yura	Ax (E)	97.23	2.10	0.12		0.16				0.37		
8	id	Disk (C)	91.97	7.50	0.11		0.17				0.13		
9	id	Pin (D)	90.15	9.30	0.14		0.06				0.28		
10	id	Plate	88.47	10.72	0.28		0.08				0.37		
11	Cobrizos	id	59.20			39.38					1.33		
	ECUADOR.												
12	Ecuador	Ax (K)	99.43		0.22						0.27		
	ARGENTINA.												
13	Tastil	Chisel (H)	99.70		0.08						0.17		
14	Calchaquí Region.	Ax (F)	99.10		0.30						0.46		
15	La Poma	Fragment	90.75		Traces.						2.51	5.20	1.46
16	Tastil	Disk (C)	97.02	2.48	0.11						0.31		
17	Pucara	Pendant (M)	96.62	3.04	0.07						0.24		
18	Sansana	Knife (B)	95.97	3.65	0.13						0.21		
19	La Poma	Bell (G)	95.60	3.92	0.14						0.29		
20	Morohuasi	Chisel (H)	95.06	4.43	0.12		Traces.				0.37		
21	Molinos	Bell (G)	93.70	6.00	Traces.						0.27		
22	Conchas	Disk (C)	92.20	6.91	0.32						0.44		
23	La Poma	Fragment	91.65	7.68	0.24						0.39		
24	id	Ball (T)	89.85	9.40	0.32						0.41		
25	id	Chisel (H)	85.60	13.52	0.64						0.17		
26	Golgota	Bracelet (J)	85.77	13.69	0.09		Traces.				0.33		
27	Calchaquí Region.	Knife (B)	95.90	3.80							0.28		Traces.
28	id	Ax (F)	91.40	7.38							1.05		
			93.58	6.06	Traces.								
29	id	id	92.67	4.40	1.80						0.91		
			96.66	3.34	Traces.								
30	id	Ax (F)	94.26	5.73	Traces.								
31	id	Bell (G)	91.20	6.00							Tr.		
32	id	Disk (L)	98.42	1.57	Traces.								
33	id	id	97.41	2.00							0.56		
34	id	id	97.40	2.12							0.46	Traces.	
35	id	id	96.00	2.43	Traces.						1.54		
36	id	id	95.49	2.43							1.79		Traces.
37	id	id	97.25	2.52						0.22			Traces.
38	id	id	94.98	2.58	0.22	1.65		0.23		Traces.	0.11		
39	id	id	97.25	2.90									
40	id	id	94.95	3.03	0.21	0.94		0.33			0.37		
41	id	id	94.00	3.07	1.04	1.15		0.36		Traces.	0.08		
42	id	id	96.85	3.14									
43	id	id	93.55	3.46	0.18	1.01		0.82			0.75		
44	id	id	94.57	5.43	Traces.								
45	id	id	91.80	5.66					2.04		0.50		
46	id	id	91.79	6.64	0.14	0.81					0.50		
47	id	id	90.06	8.67					0.78		0.28	Traces.	
48	id	id	83.47	16.53									

An examination of the composition of the different objects analyzed shows, first, out of forty-eight, six of copper, forty-one of bronze, and one of brass. Of the copper pieces three were nearly pure, for they contained more than 99 per cent of copper, with only a few tenths of a per cent of lead and iron. These were a chisel (No. 13), a large ax with shoulders (No. 14) from Argentina,

and a heavy ax with a tang (No. 12) from Ecuador, of hard and sonorous copper quite remarkable in its quality. The two bolts from Tiahuanaco (Nos. 1 and 2) were the only Bolivian copper pieces analyzed.

Like all products of a primitive metallurgy, the bronze objects contain, besides copper and tin, certain other metals, but in a very small proportion.

The majority of the analyses showed lead (from 0.07 to 1.80). In only two specimens was found more than 1 per cent.

Zinc was also discovered in several disks from Argentina (from 0.81 to 1.65).

Antimony was encountered in very small quantities, but quite uniformly in all the Bolivian bronzes (generally 0.06, rarely up to 0.17), while it was totally lacking in those from Argentina.

Bismuth was found in several of the Argentine bronzes (from 0.23 to 0.82).

Two Argentine disks contained nickel (0.78 and 2.04).

Silver was just as scarce. A disk from the Calchaqui region showed 0.22; two others merely traces.

On the other hand, the analyses of nearly all the bronzes gave iron in proportions varying from 0.08 to 1.79; but, of thirty-four pieces, thirty-one contained less than 1 per cent. It is perfectly evident that the iron, as well as the other accessory metals just considered, was not introduced into the composition of these bronzes intentionally. They were probably found naturally either in the copper and tin ores used in the manufacture, or in the attle around these ores.

As to the essential constituents of these bronzes, copper and tin, their proportions are very variable. The specimens from Tiahuanaco contained from 5.83 to 7.70 per cent of tin, while those from Yura from 2.10 to 10.72 per cent. In the bronzes from the Argentine Republic the variance was even greater—from 1.57 to 16.53. Altogether, of forty-one pieces, only four were found containing more than 10 per cent of tin, the normal proportion in bronze. The mixture of these two metals was certainly intentional. It furnishes us with irrefutable evidence that the tribes living in the mineral-bearing regions of the Bolivian and Argentine Andes before the advent of Europeans were familiar with tin, which they knew how to extract and alloy with copper. But the unequal proportions of tin shown in their bronzes demonstrates that they possessed only quite rudimentary ideas on the metallurgy of this latter metal.

We have seen by the impurities brought to light in the analyses that the refining of metals was very imperfect. Likewise the combination of their constituents seems to have been rather empirical. *It has been shown*, for example, that it is not in the objects in which a

large proportion of tin would have been particularly useful that the greatst percentage occurs. Thus, among the bronzes from Tiahuanaco, the metal of a knife (No. 3) contains only 5.83 per cent of tin, while that of a pin (No. 6) has 7.70 per cent. From Yura, a utensil, a very thin cutting ax (No. 7), had in its composition only 2.10 per cent, while two objects purely for decorative purposes, a pin (No. 9) and a plate (No. 10), contained up to 9.30 and 10.72 per cent. The contrary would be indisputably more logical. It is important to note that the three pieces came from the same region and belong to the same period.

More curious still are the observations on this subject which can be made from the Argentine bronze analyses. A knife (No. 18) revealed only 3.65 per cent of tin; but 13.69 per cent was found in a bracelet (No. 26). The bells, which should have an alloy rich in tin, contained only a comparatively small amount—6 per cent in two specimens (Nos. 21 and 31), and as little as 3.92 in another (No. 19). The only piece of actual white bronze, or bell metal, was a decorative object (No. 48) whose proportion of tin was 16.53 per cent. As for the rest of them, in one and the same category of objects, the quantity of tin still varied considerably.

In regard to the big axes with lateral shoulders (fig. 5), of which four examples were analyzed, two of them twice, what do we find? First, a specimen of pure copper with no trace of tin (No. 14), and the others (Nos. 29, 30, and 28) with 3.34 or 4.40, 5.73, 6.06 or 7.38 per cent respectively. It is the same in connection with the ornamented disks attributed to the Calchaqui peoples. We have a number of analyses of their metals. Leaving out of consideration the exceptional specimen containing 16.53 per cent of tin, discussed above (No. 48), it is seen that the rest, sixteen in number (Nos. 32 to 47), possess tin in quantities ranging in progressive order from 1.57 to 8.67 per cent. The average is 3.60.

There has also been mentioned a brass object concerning which something should be said. The appearance of this piece is unique. Its pale yellow color and the absence of all traces of oxidation caused it to be taken at first glance for a small plate of gold. The analysis showed that it was merely a sheet of brass, probably not of ancient origin. The metal composing it contains in round figures sixty parts of copper and forty of zinc, very nearly the composition of brass from which present bronzes of very inferior quality are made. By chemical analysis we are thus able in certain cases to tell whether these objects are, as regards their age, of a period before or after the conquest. Analysis likewise furnishes us with valuable evidence as to the authenticity or nonauthenticity of certain pieces, just as in the experi-

ment undertaken by Ambrosetti. Four specimens of metals from objects that were not genuine furnished the following results:

	Copper.	Zinc.	Tin.	Lead.
1	75.06	12.51	8.02	4.42
2	73.46	13.88	8.10	4.56
3	84.11	14.31	1.30	----------
4	82.08	14.66	.70	1.22

These alloys, very different from those known to the ancient inhabitants of the country, bring to mind the composition of the brasses and inferior bronzes from which are manufactured many objects of modern industry.

SOME OPPORTUNITIES FOR ASTRONOMICAL WORK WITH INEXPENSIVE APPARATUS.[a]

By Prof. GEORGE E. HALE,

Director of the Mount Wilson Solar Observatory of the Carnegie Institution of Washington.

I have sometimes heard it said that the great cost of modern observatories tends to discourage workers with small instruments—observers who are no less interested in the pursuit of astronomical research than the astronomers in the large institutions. It seems to me that if there is any serious discouragement, due to this cause, of men who are engaged in original research with small telescopes and inexpensive apparatus, it is a question whether large observatories should be established. At any period in the progress of observational astronomy there are two most important subjects for consideration. One relates to the accomplishment of a great amount of routine observation and the discussion of results, and the other relates to the introduction of new ideas and to the beginnings of the new methods which will make the astronomy of the future. I think we will all admit that the introduction of new ideas is quite as important as the prosecution of routine research, and that if any cause whatsoever tends to discourage the men from whom the new ideas might be likely to proceed, that cause of discouragement should be set aside if possible. And therefore I say, with all seriousness, that it is a fair question whether large observatories, with powerful instrumental equipment, should be established if they tend to keep back the man who is pursuing the subject with less expensive appliances, and is introducing, through his careful consideration of the possibilities of research, the new methods which in the process of time will take the place of the old ones. I think it can be shown, however, that the large observatories should be a help rather than a hindrance, at least by suggesting new possibilities of research, in which most valuable results can be obtained by simple means.

[a] Stenographic report of a lecture delivered at the Royal Astronomical Society, London, June 26, 1907. Reprinted, by permission, from the Monthly Notices of the Royal Astronomical Society November, 1907.

I am talking to-night, in purpose at least, to the amateur; but my definition of the amateur is perhaps a broader one than is generally accepted. According to my view, the amateur is the man who works in astronomy because he can not help it, because he would rather do such work than anything else in the world, and who therefore cares little for hampering traditions or for difficulties of any kind. The "amateur," then, is the person to whom I wish to address my remarks, whether he be connected with a small observatory in the capacity of professional astronomer, or working by himself with very simple instrumental means. But in speaking to the amateur I do not wish to deal with work that shall be satisfactory merely from the standpoint of instruction or amusement. That is not my purpose. If it is possible to carry on research by simple means that shall really be important and useful, it is my hope to point out some such possibilities. But I do not wish to speak of any work except that of the first class, nor to recommend that any investigations should be undertaken with simple instruments that are not quite as important as other investigations which can be better undertaken with more expensive instruments.

The problem then becomes one of this character—to determine the relative advantages of large and small telescopes for different classes of research, and the possibility of constructing really powerful instruments at moderate expense. I can not pretend to discuss all phases of this large problem; I shall mention only a few of them, and approach it from a single direction. But before taking up the details of this discussion, perhaps I may be permitted to say that the conception that is sometimes formed of the newer observatories, the idea that vast sums of money are expended, perhaps without the fullest sense of economy, is not always well founded. For I am quite sure that if you would visit us (to take a single concrete case) in California, you would agree that we have considered the economical side of the question, that we have perhaps in some instances gone almost too far in our desire to save money for instruments of research, and to economize in certain directions where money can be saved. For example, you would find that our offices, our buildings, are of the simplest and least expensive character, while our instruments and machinery are as effective as we can make them. The great expense of such an observatory as the Solar Observatory on Mount Wilson does not depend in large degree on the cost of the instruments used for investigations of the sun, but in surmounting the difficulties encountered in utilizing a mountain site, deprived of the ordinary means of transportation, and in the construction of large equatorial reflecting telescopes for stellar work, which can not be built cheaply if they are to be really efficient.

I wish now to come to the question before us, and to illustrate *some of the* advantages and some of the disadvantages of large and *small instruments*. Perhaps you will permit me, in showing the

first slide on the screen, to say that I have some right to undertake a discussion of this sort, because I have viewed the subject from the standpoint of the man using small and inexpensive apparatus. In my first spectroscopic work, which was done in a room in my father's house, the instruments were of the simplest character, and largely of my own construction. Later, a small building was constructed for a concave grating of 10 feet focal length, and the apparatus, although powerful, was not expensive. Subsequently a tower and dome were added, and a 12-inch telescope was erected for photographic work upon the sun. After the preliminary experiments had been completed, and the spectroheliograph had begun to take form, the possibility that its results could be greatly improved through the use of a larger telescope suggested itself, and for this reason I made many efforts to acquire a large instrument for these solar investigations. The result, through the generosity of Mr. Yerkes, was the 40-inch Yerkes telescope, which proved to be very useful for the extension of the spectroheliograph work. The next slide shows the instrument, which you will see is a large and expensive machine. The question, then, comes right down to this point: What are the advantages of such a telescope compared with, let us say, a 6-inch equatorial or possibly a 4-inch equatorial? Is it possible with a 6-inch equatorial to do work comparable in importance with the work that can be done with a 40-inch equatorial?

The next slide will show that there was an advantage in passing from the Kenwood 12-inch to the Yerkes 40-inch, at least for the photography of the sun. Very minute details of the flocculi were brought out which had not previously been known. But it may easily be shown that the advantages of the 40-inch telescope for most classes of solar work are due more particularly to its great focal length than to its large aperture.[a]

Let us take another illustration. Here we have a picture of the moon made by Professor Ritchey with the 12-inch Kenwood telescope. You will notice that near the terminator is the crater Theophilus, which you will see again in the next slide as photographed with the 40-inch telescope. This photograph taken by Professor Ritchey is probably as good a photograph of the moon's surface as has yet been made, and in this case the advantage of the 40-inch telescope is apparent.[b] But if we take another case, as illustrated in the next slide, it becomes obvious enough that for certain classes of work the Yerkes telescope is not well suited. Here is a picture made with the 40-inch

[a] So far as resolving power is concerned, an aperture of 8 inches would be sufficient to permit the smallest known details of the flocculi to be photographed.

[b] Here, again, the full visual resolving power is not utilized, but the great aperture is of advantage in permitting the large image to be photographed with very short exposures.

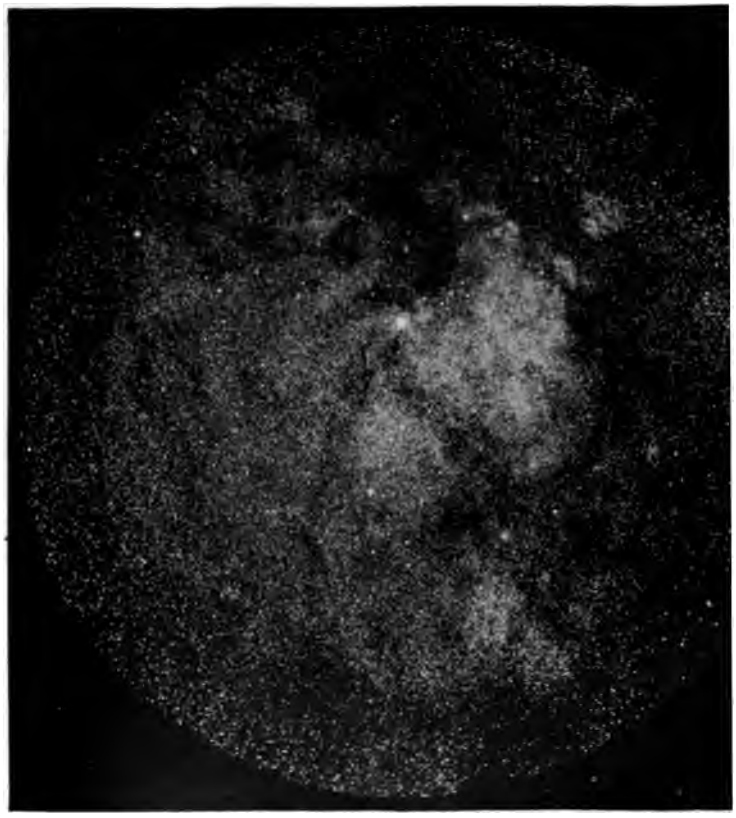
of the Andromeda Nebula. You see how little it shows, since a long-focus telescope, unless of very great aperture, is not well adapted for the photography of faint nebulæ. When we compare this picture with the next one, made by Professor Ritchey with the 2-foot reflector (of 8 feet focal length), we appreciate immediately that the 40-inch, in spite of its great advantages for certain classes of work, is wholly unadapted for other investigations. As you know, a refractor of much smaller aperture and of shorter focal length would also give a photograph of the Andromeda Nebula far superior to anything that could be taken with the 40-inch.

If we look at the next slide, which shows Professor Barnard's 10-inch Bruce telescope when it was mounted on Mount Wilson, where he was using it to photograph the Milky Way, you will see an instrument that is very small and inexpensive as compared with the Yerkes telescope. It has a 10-inch Brashear lens of 50 inches focal length and certain smaller cameras attached to the side of the tube. With such an instrument as this, superb photographs of the Milky Way, like the one illustrated in the next slide, can be taken, which are indispensable for investigations on the distribution of stars in this part of the heavens. Excellent work can also be done with a much smaller lens, provided with a very simple mounting.[a] A fine instance of systematic work with a portrait lens is afforded by Mr. Franklin-Adams's photographic map of the northern and southern heavens.

It is hardly necessary to recall the fact that the 40-inch could not do this work at all. If we attempted to photograph the Milky Way with it, we might get a very small region on a very great scale, but to give us any notion as to the general distribution of stars in the Milky Way the 40-inch would be a total failure. However, if it were a question of studying some star cluster like the one shown in this slide, which would occupy a very small region indeed of the Milky Way, the 40-inch would enable us to pick out the separate stars, to study their individual phenomena, their changes in light and position, while such work could not be done on photographs taken with a portrait lens.

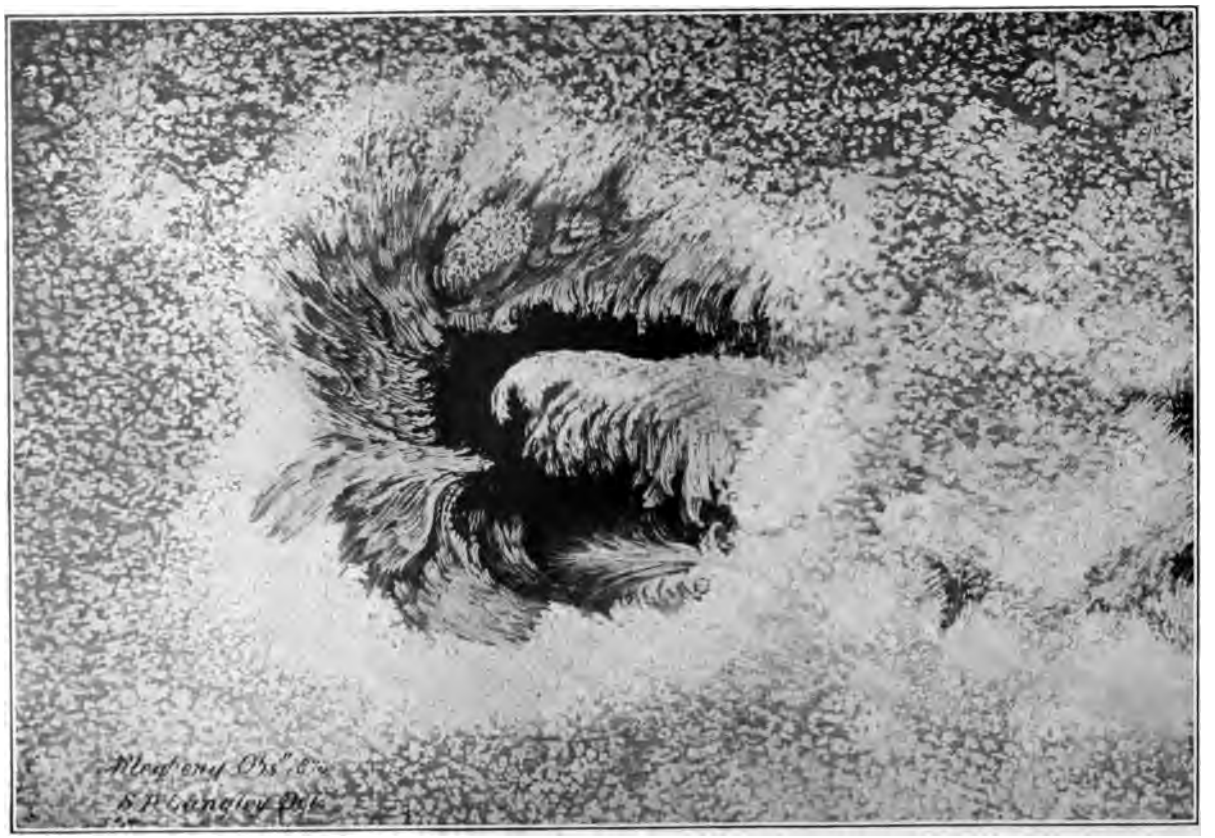
I have shown these miscellaneous illustrations for the purpose of emphasizing, what is perfectly well known to all of you, that each instrument has its particular fields of work, in which it can accomplish, or permit to be accomplished, various investigations which are not within the reach of other kinds of telescopes. But I now wish to discuss the question somewhat more specifically,

[a] Professor Barnard has illustrated in the Astrophysical Journal some of the admirable results he has himself obtained with a cheap "lantern lens" belonging to an ordinary stereopticon. A photograph obtained by him with this lens *is reproduced* in plate I.



STAR CLUSTER MESSIER 11 AND THE SURROUNDING MILKY WAY.

Photographed on Mount Wilson with a small stereopticon lens by Professor Barn



A TYPICAL SUN-SPOT.

From a drawing by S. P. Langley.

and in doing so I shall confine myself almost entirely to observations of the sun, although one might attack the subject from many other directions. The first point is this: Suppose one has a small telescope of 4 inches or 6 inches aperture and wishes to observe the sun with it; and let us assume at the outset that he has no attachments whatever in the form of spectroscopes, but that he wishes simply to make direct observations of the sun. Is there work for such an instrument at the present time? If you will examine the literature of the subject you may perhaps be surprised to find that many years have elapsed since very careful and extensive investigations have been made similar to those of Langley, which may be almost forgotten by many astronomers, but certainly are not forgotten by those of us who follow the sun and are accustomed to the appearance of the spots when the definition is good. The next slide shows the well-known drawing of Langley's typical sun spot. (See plate II.) You will remember, if you have systematically observed the sun, that every time the conditions become extremely good, the structure of sun spots more and more closely resembles this drawing. This is a typical drawing; it does not represent any particular spot; it brings together observations of various spots; but in general the details of a sun spot look very much indeed like that drawing when the definition is good enough to show them properly. This subject has been greatly neglected for a long time, and it would well repay observers with large or small instruments to observe sun spots, and to study many of the details of their structure which still remain obscure and difficult to understand.[a] Of course the question of the resolving power of the instrument must then be considered. A 4-inch telescope, capable of separating objects one second of arc apart, would not do for the very finest details in a sun spot. According to Langley, the penumbral filaments sometimes exhibit structure considerably smaller than such a telescope would show; but a 10-inch or 12-inch telescope would show everything that has ever been recorded in a sun spot, and there are many instruments of that size available for such observations.[b] Even a much smaller telescope, if carefully and systematically used, would contribute largely to our knowledge of sun

[a] For example, it would be of great interest to study the structure of the umbra, as seen through a minute pin hole in the focal plane of a positive eyepiece, as Dawes did many years ago.

[b] It must not be forgotten that photography is still behind visual observations in revealing the minute structure of sun spots. It can hardly be doubted, however, that if only the umbra and penumbra were permitted to fall on the plate, and the exposure properly regulated, new and valuable results would be obtained. The amateur will readily find many opportunities for work in this field.

spots and of the structure of the solar surface. I might enlarge upon this subject, but time is hardly sufficient to permit me to do so.

Now let us consider the case of the prominences. If we have available a small spectroscope like that admirable little instrument designed by Evershed, or the one made by Thorp,[a] or a still simpler home-made instrument, and attach such a spectroscope to a 4-inch or 6-inch telescope, we have an almost ideal equipment for the observation of the solar prominences. As a matter of fact, an instrument like the 40-inch is wholly unsuited for work of this kind. You will easily see why. If you wish to observe the entire prominence, its image in the focal plane of the 40-inch telescope is usually so large that the slit can not be opened wide enough to include the prominence without admitting too much light of the sky. Therefore, for a study of the general characteristics of prominences, the small instrument has a great advantage over the large one. It was practically out of the question with the 40-inch for us to do systematic visual work on prominences. When the conditions were peculiarly fine we could study the structure of certain prominences, and I never saw anything more remarkable than such details when they came out under the best seeing. But with the spectroscope available, and under ordinary atmospheric conditions, we could not make records of the general form and distribution of prominences that would compare in value with the records obtainable with small telescopes.

It has remained for certain amateurs here in England very recently to show that objects upon the surface of the sun which escaped many of the earlier solar observers can be observed at any time when the conditions are favorable with a very small instrument indeed. For example, Mr. Buss and Captain Daunt, and, I believe, some others, have been observing the sun with such instruments, and have been able to see upon the disk dark regions in which the D_3 line is strengthened, which I think have never been recorded before in a systematic way. Observations of the dark D_3 line upon the face of the sun were formerly mentioned as unusual and rather remarkable phenomena, and certainly, so far as I have ever seen in the literature of the subject, the dark hydrogen flocculi were never recognized upon the sun by the earlier spectroscopists; but they are seen, at times at least, by those gentlemen to whom I have referred. This I can make quite certain from my own knowledge, because on one occasion, when Mr. Buss had described one of the very peculiar dark hydrogen flocculi—flocculi of this type appear very much darker than the ordinary ones photographed daily with the spectroheliograph—I looked

[a] I wish to call special attention to the solar spectroscopes and other inexpensive instruments made by Mr. Thomas Thorp, of Manchester. One of these, *a polarizing helioscope*, has done excellent service on Mount Wilson.

up our photographs of that date, and there was the image recorded by the spectroheliograph precisely as it had been described. So that if I had previously been a little doubtful as to the possibility of seeing these objects with such an equipment, I gave up all doubt after having made that comparison.[a] One might say that it would hardly be practicable to observe such phenomena in any satisfactory way with a large telescope. A small one is very much more advantageous for work of this kind. As soon as possible we are going to set up a small equatorial for the purpose of seeing these objects and comparing them with our photographs, after having derived the knowledge of the possibility of observing them from the work done by these men in England. But we will not undertake systematic work in this field, as I hope the valuable observations now in progress here will be continued. No records are made with the spectroheliograph of the D_3 image of the sun at present. We have tried experiments, but so far they have not been successful. We ought to be able to photograph the sun through the D_3 line, but we have not done it yet. The only existing records are those made by the members of the British Astronomical Association. These observations should be made in conjunction with other solar observations, as in fact is being done at the present time. The characteristics of the hydrogen lines are being observed at the same time that these D_3 images are being recorded, so that any relationship between the two may be discovered. I can not dwell upon this very interesting subject. There is a great opportunity here for further work of high importance.

I must now pass to the question of sun-spot spectra. I need hardly tell those who are present that observations of sun-spot spectra made visually are sometimes more valuable than those which can be made by photographic methods. Take, for example, the lines in the green region of the spectrum. This photograph will suffice to show them. Here is the *b* group in the spectrum of a sun spot and also in the spectrum of the photosphere. We see in the spot a large number of fine lines, long ago observed by Young and Maunder, and now being studied with great care. Most of these fine lines shown by a powerful instrument photographically can be seen visually with a small spectroscope attached to a 6-inch or probably a 4-inch telescope, and many other phenomena which can not be photographed at all can be seen with a similar equipment.[b] There is a certain advantage in observing such spectra with a larger telescope, provided that the spot under con-

[a] As I understand the matter, only the more conspicuous dark flocculi can be observed visually.

[b] Since the lecture was given much better photographs of spot spectra have been made with the 30-foot spectrograph and "tower" telescope on Mount Wilson. It still remains true, however, that visual observers of spot spectra can obtain various important results not yet within the reach of photography.

sideration is a small one. But if the spot is a fairly large one (and hitherto no one has had time to observe the spectra of small spots systematically), I think there is no advantage whatever in having a large telescope to form the image of the sun on the slit of the spectroscope; it is merely a question of having an image of moderate dimensions upon the slit, and after that the spectroscope does the work. So that, so far as the larger spots are concerned, a small telescope is quite as satisfactory as a large one for *visual* work on their spectra.

I will return in a moment to the question of the relative advantages of the photographic and the visual methods of observing spot spectra; but I want to point out in passing that the 40-inch telescope has certain very definite advantages for work on the sun. If one wishes to observe the spectrum of the chromosphere, for example, the advantages of great focal length immediately become apparent. The width of the spectroscope slit is essentially constant; the chromospheric arc must have a certain linear width on the slit in order to permit the base of the chromosphere to be observed; and consequently the spectrum of the chromosphere, as seen with the 40-inch telescope, is a remarkable sight, showing thousands of lines which do not come out with a small focal image of the sun.

Here we have, then, an illustration of the advantages for certain purposes of considerable focal length. I think it is not so much a question of the telescope's aperture here, because we must not forget, in thinking of the optics of this question, that the brightness of the spectrum (for constant purity) is quite independent of the linear or the angular aperture of the object-glass that forms the image of the sun on the slit of the spectroscope.[a] Perhaps it is well to bear in mind that the brightest solar spectrum one can get is obtained without any telescope whatever to form an image on the slit, but merely with a collimator of suitable angular aperture. But a large solar image is frequently advantageous, and an equatorial telescope of great focal length is necessarily an expensive instrument. The aperture in the case just mentioned is less important than the focal length; but even if the aperture were only 6 inches and the focal length unchanged, the tube must still be 64 feet long, and the mounting would cost no less than the mounting of the Yerkes telescope. So if we wish to have an instrument of great focal length, and yet keep down

[a] When the focal length of the collimator is limited (as is usually the case in a spectroscope attached to an equatorial telescope), an increase in the angular aperture of the telescope permits the linear aperture of the spectroscope, and consequently the resolving power and the brightness of the spectrum, to be increased up to a limit fixed by the size of the grating available. With a cœlostat telescope, however, the same conditions do not obtain, since the aperture of the spectroscope can be increased by merely increasing the focal length of the *collimator.*

COELOSTAT AND SECOND MIRROR OF SNOW TELESCOPE.

CONCAVE MIRROR OF SNOW TELESCOPE.

the expense to a reasonable figure, we must use a telescope of a different type. There are many other reasons why we should wish to use a fixed telescope for certain kinds of solar work, although I should be the last to admit that the 40-inch telescope is not an almost perfectly satisfactory machine of its kind. It has, as we have seen, inconveniences and disadvantages for some classes of work, but in other fields its superior qualities become more and more striking day after day as the observer learns to appreciate them. I only wish we could afford to have such a telescope (or even a much smaller equatorial refractor) on Mount Wilson, as it would be of great service for many purposes.

Now let us consider some of the possibilities of the fixed telescope; and let me show, for purposes of comparison, a picture on the screen of the Snow telescope which is now employed at Mount Wilson (plate III). Here is a cœlostat, with mirror 30 inches in diameter. After passing to a second mirror the light is reflected to a concave mirror of 60 feet focal length (plate IV), which sends it back and forms a large image of the sun within a laboratory. This is a very simple instrument indeed. The first cœlostat we set up on Mount Wilson was a small one used by the Yerkes Observatory party at the eclipse of 1900, and it was not originally arranged for work of this kind; so we simply built a wooden support for a second mirror, and with the aid of a 6-inch objective of 60 feet focal length we made a telescope which served admirably for our solar work until this one was put up on the mountain.

The next photograph shows the spectograph used with the Snow telescope. It is of the Littrow or autocollimating type, with slit and plate holder at one end of a long tube and lens and grating at the other. Light from the solar image, after passing through the slit, falls on the lens 18 feet (its focal length) distant. The rays, thus rendered parallel, then strike the grating and are returned to the lens, which forms an image of the spectrum on the photographic plate, just above the slit (the grating being tipped back a little). Such an outfit (fixed telescope and spectrograph) is an extremely simple thing to build in inexpensive form. Cœlostats, for example, are common nowadays for eclipse work. One might have a cœlostat with a mirror only 6 inches in diameter and a second mirror about 4 inches in diameter, and then perhaps a telescope lens of 4 inches aperture and 40 feet focal length. Such an instrument as that, which could be built very cheaply indeed, would give a large solar image, adapted for many kinds of solar work.

Let me show you in the next slide how we build our spectrographs in actual practice. This is the most powerful spectrograph in use in the laboratories of the Solar Observatory. Here is a little slit I bought from Hilger, the last time I was in London, for a few shillings. All other *parts of* the spectrograph, except a lens and grating,

are of wood, built in a few hours by a carpenter.[a] The wooden support for slit and plate holder stand on a concrete pier, and close an opening through a partition which forms one end of a narrow dark room. Eighteen feet from the slit, within the dark room, is another concrete pier. A sliding wooden support, carrying a lens, and a simple wooden mounting for the grating, stand on this pier, and complete the spectrograph. (A similar spectrograph, suitable for use in an open room, is illustrated in plate v.) Owing to the scarcity of gratings, we are fortunate in being able to use one loaned by Professor Ames, of Johns Hopkins University. If we had no reflecting grating, we could buy a replica very cheaply from Thorp, or Wallace, or Ives,[b] which would give quite as good photographs as we obtain now (though the exposures would be longer, because of the smaller aperture). They might even be better, because our photographs of spot spectra (made with the similar spectrograph of the Snow telescope) are not what they ought to be, or what I hope they will subsequently become.[c] They would not stand comparison for a moment, so far as perfection of definition is concerned, with those magnificent photographs of the solar spectrum made by Mr. Higgs in the center of Liverpool, under conditions which would ordinarily be called very bad even for a crowded city, with tram cars constantly passing in front of the house. With a spectrograph of his own construction (except the grating), Higgs made the finest photographs of the solar spectrum ever produced; superior, as Rowland would have said, to the best photographs made by himself at the Johns Hopkins University. It is obvious that something other than an expensive instrument is required to make a good photograph. Mr. Higgs has the ability, which others may acquire, to obtain superb definition and exquisite photographs with very simple apparatus indeed.

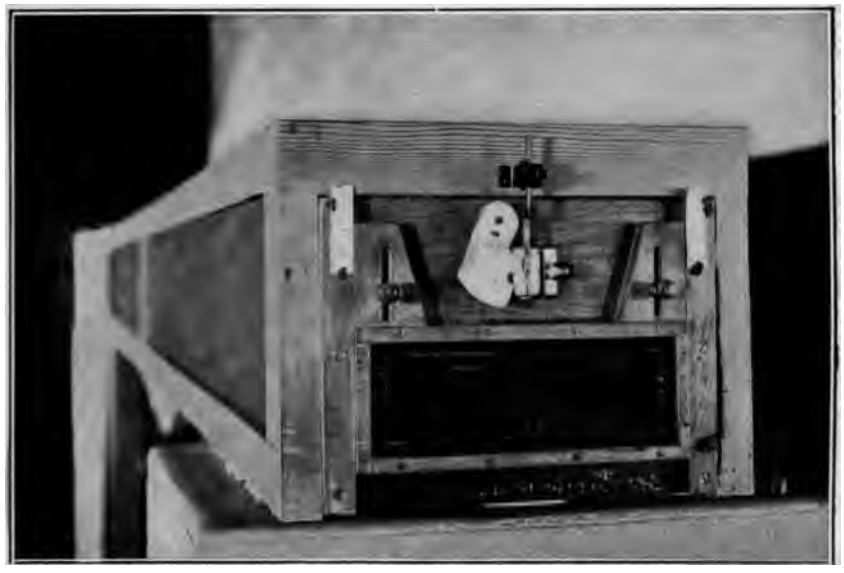
With a spectrograph of 1 inch aperture and 10 feet focal length, used with a fixed telescope of 4 inches aperture and 40 feet focal length, one would be in a position to make good photographs of the spectra of sun spots.

What, then, are the relative advantages of visual and of photographic work? The next slide shows some photographs. The upper one is the spectrum of the sun and the lower one is that of a spot. These photographs are better than visual observations for the determination of the wave lengths of unknown lines in spot spectra, simply

[a] Except the plate holder, which is of a standard make.

[b] As these replicas are not reflecting gratings, the auto-collimating spectrograph might in this case give way to one in which a separate camera lens is used. With the angular aperture here considered, well-made simple lenses would obviously serve perfectly well for collimator and camera, the photographic plate being set at the angle required to bring a sufficient range of spectrum into focus.

[c] *See footnote on p. 273.*



SLIT AND PLATE-HOLDER END OF SIMPLE WOODEN SPECTROGRAPH OF LITTROW OR AUTO-COLLIMATING TYPE (18 FEET FOCAL LENGTH), USED IN THE SPECTROSCOPIC LABORATORY ON MOUNT WILSON.

[Not the instrument referred to in the lecture, but a similar one, suitable for use in an open room.]

GRATING AND LENS SUPPORTS FOR MODERN SPECTROGRAPH (18 FEET FOCAL LENGTH), USED IN THE SPECTROSCOPIC LABORATORY ON MOUNT WILSON.

The bar for cutting off reflections from the lens is shown.

because you can measure the position of a line on the photograph to much better advantage than you can do it visually at the telescope. They are also better for the determination of the relative intensities of the lines, especially the fainter ones. But when you have said that, you have said almost everything that can be said for the photographs, and you have left out of account many of the very important advantages of visual observation. These photographs represent the integrated spot spectrum, as it were. Even with a large image of the spot on the slit of the spectrograph (and you realize here that the principal point of our great focal length is to have a large image of the spot on the slit), we can not as yet satisfactorily record minute differences in the spectrum corresponding to small details in the spot. If we wish to study these very important differences in the spot, we must do so, at present at any rate, by visual means. For example, Mr. Newall, your president, told me the other day that he had found the spectrum of the outer edge of the penumbra of a spot to have the same characteristic strengthening of the lines that is observed in the umbra, which is a very difficult thing to explain from the standpoint of the hypothesis I have been favoring of late, viz, that the principal cause of the change of the relative intensities of lines in a spot is reduced temperature of the vapors in the umbra. I knew nothing about that; I had not been observing the spot spectrum visually for many years, and in our photographs this phenomenon is not recorded. You see, then, in such a case the decided advantage of visual observations. I might go on to speak of other advantages. For example, suppose there were a sudden change in the spectrum due to an eruption; the chances that one would get a photograph just at that time are small, whereas visual observations necessarily occupy a considerable period of time, during which eruptions might be detected.[a] Even a few results might be of extreme importance, and would probably be wholly missed in the photographs. Again, the extension of certain lines outside of the spot upon the photosphere is not recorded at all in our photographs, because of the method we usually employ of excluding from the plate all light except that which comes from the umbra, and perhaps part of the penumbra. We ordinarily get no trace of these extensions, but perhaps the conclusions drawn from the study of such phenomena may have much to do with the final views as to the nature of the spots themselves.

To mention only one other thing, the reversals of spot lines which have been seen by some observers have not been photographed with

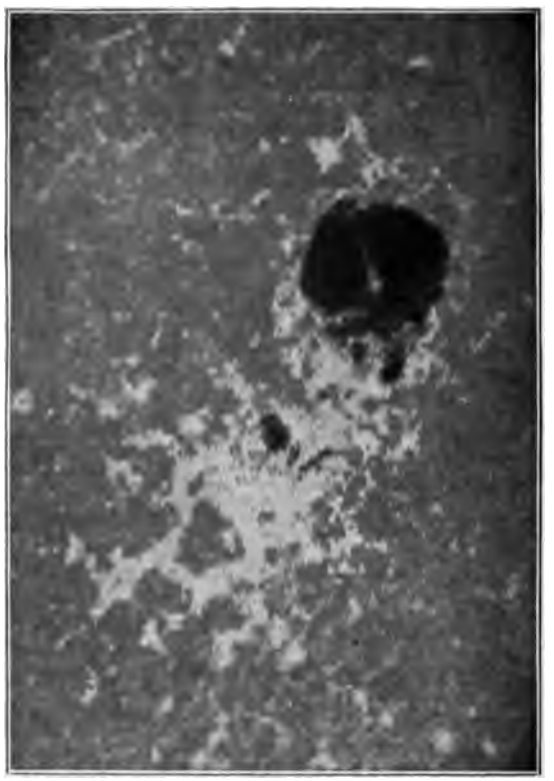
[a] It is, of course, desirable to take photographs as often as possible, since a photographic record of a marked change in the spectrum, if fortunately obtained, may be much more valuable than the results of a few visual observations made hastily.

At each corner of the platform was screwed a small cast-iron block, in which a V-shaped groove had been planed. In each groove was a steel ball. A moving platform, also built of wood, carried the optical parts of the spectroheliograph and rested on these balls, so that it could be moved across the image of the sun (formed by a cœlostat telescope). The motion was produced by a small electric motor, belted with a piece of fish line to this large wooden pulley, which drove a screw passing through a lead nut fastened to the movable platform. The screw was cut on a foot lathe and the nut cast on it. This simple mechanism provided the means of producing a slow uniform motion of this upper platform across the image of the sun. The arrangement of the optical parts was precisely the same as in the Rumford spectroheliograph.

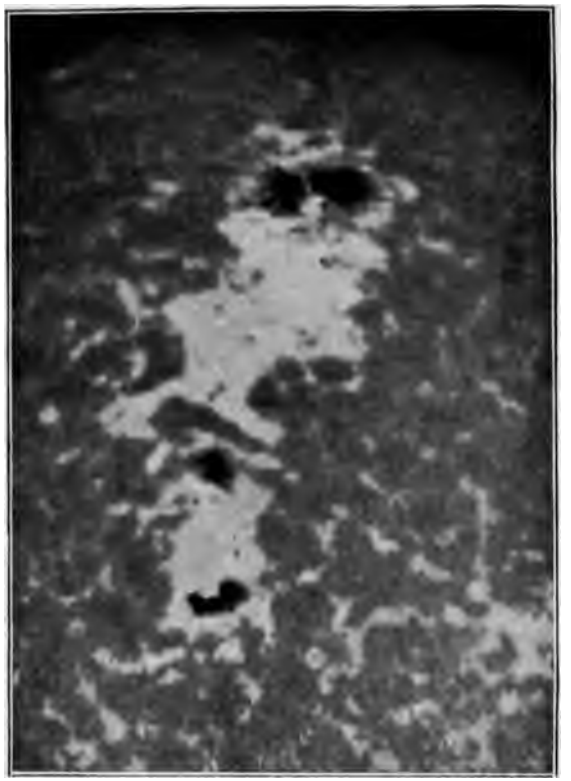
Looking at the instrument in plan, we have a slit here (*a*) through which the light passes. A very simple slit will do. This was an old one; I think it came from a portion of the old Kenwood spectroheliograph. The light passed through this slit and fell on a collimating lens (*b*), which may be an ordinary uncorrected lens if the focal length is sufficient. We happened to have some achromatics which we used, but they were no better than a simple lens would be. The parallel rays fell on a plane mirror here (*c*), and were reflected to these prisms (*d*, *d*). We used two prisms, but one will do perfectly well, unless hydrogen as well as calcium flocculi are to be photographed. These prisms had been discarded; they were originally made for the Bruce spectrograph, but they were so poor that they could not be advantageously used for stellar spectra, so we borrowed them from the Yerkes Observatory and put them in here. The two prisms, with the mirror, gave a total deviation of 180°. The light then passed through the camera lens (*e*)—here, also, a simple lens will serve very well—which formed an image of the spectrum on a second slit (*f*), close to the fixed photographic plate (*g*). By setting this slit on the H_2 line of calcium, and moving the instrument slowly across the solar image with the motor, excellent photographs of the calcium flocculi were obtained.

The next slide shows some photographs taken with the permanent instrument. Such photographs as these, made with the calcium and hydrogen lines, open up for investigation a large field, which anyone can enter with just such an equipment as I have described—a very simple instrument, with small prisms and lenses, and built almost entirely of wood.

I will show you in the next photograph some pictures obtained with the wooden instrument. You will notice that in this case the motion was not absolutely uniform; you can detect the slight irregularity of motion, but it did not affect the usefulness of the negatives. This is a direct photograph of the sun; this is made with the H_1 line



July 17, 1905, $17^h\ 56^m$. Low-level calcium flocculi slit set on H_1 (λ3,966). Sun's diameter = 0.28 meter.



July 20, 1905, $5^h\ 18^m$. High-level calcium flocculi slit set on H_2. Sun's diameter = 0.28 meter.

PHOTOGRAPHS OF CALCIUM FLOCCULI MADE WITH A SIMPLE WOODEN SPECTROHELIOGRAPH.

of calcium, and this is the same region as photographed with the H_2 line of calcium. If somebody would go to work with such an instrument and let us know exactly what such photographs as these mean, they would at least confer a very great favor upon me, because hitherto I have been unable to determine with certainty the relative parts played by the continuous spectrum of the faculæ and the light of the H_1 line of calcium in producing the photographs. That question is still open, and many investigations will be required to settle it beyond doubt.[a]

In this H_2 photograph we probably have a picture of the calcium vapor at a higher level than the level represented by the H_1 plates. You see, for example, this bridge of calcium vapor across the spot, which is not shown by H_1. Many investigations of great interest could be carried on with such a spectroheliograph as I have described. I wish I had time to go into them; there is only one I may mention, and that is the comparison of the calcium and the hydrogen images. Mr. Butler has asked me to explain to-night a point which I unfortunately failed to make clear in my talk here at the last meeting of the society. In speaking of the relative level of the calcium and hydrogen flocculi, I said we found that the dark hydrogen flocculi are shifted somewhat toward the limb of the sun as compared with the corresponding bright calcium flocculi. The natural conclusion to which I came was that the hydrogen absorption shown in this photograph is produced at a somewhat higher level, amounting to something like 1,500 miles, than the calcium radiation which gives us this photograph. Mr. Butler pointed out to me that the photographs of the flash spectrum show the calcium vapor to rise to a higher level than the hydrogen gas, and that the difference is about 1,500 miles. There is no question about the validity of this result, and the point is to show that it is compatible with my conclusion. I think the reason is simple enough, and lies in this fact: The flocculi photographed with the H_2 line do not represent the highest calcium vapor, but a level considerably below that; whereas the *absorption* phenomena known as hydrogen flocculi apparently represent the upper hydrogen in the chromosphere, or in some cases the prominences themselves. The average level of the hydrogen absorption seems to be about 1,500 miles higher than the region from which the H_2 light of calcium proceeds. If, as occasionally happens, the highest calcium

[a] Two photographs taken with the wooden spectroheliograph are reproduced in plate VI. They are not the ones referred to in the lecture. Since the above was written, photographs of vortices in the solar atmosphere have been made on Mount Wilson with the spectroheliograph, using the Hα line of hydrogen. A simple wooden spectroheliograph would suffice to give good photographs of these vortices, which are thus open to investigation by amateurs with limited equipment.

vapor in the chromosphere is recorded photographically, it acts as hydrogen does, and gives dark absorption phenomena, due to the high level H_3 line, and not to be confused with the bright calcium flocculi due to H_2.

I see that I must rapidly draw to a close. I might mention various other methods of employing spectroheliographs, and if anyone present should be interested at some future time to take them up I shall be delighted to discuss them in detail. I may remark in passing that with a Littrow spectrograph, or any long focus spectrograph, and a fixed solar image, one can undertake other work of various kinds, such as a determination of the solar rotation, along some such plan as Dunér or Halm followed, but using different lines in the spectrum, and benefiting from the advantages of photographic methods. In all such work, cooperation with other investigators is greatly to be desired, because it might otherwise frequently happen that two men would be doing the same thing, whereas it would be just as easy for them to supplement each other's work instead of duplicating it.

One other phase of the subject which I should like to have time to discuss, but can not, is that of stellar spectroscopy. You will see that for stellar spectroscopy a large telescope in general does have an advantage. The more light one can collect and concentrate in a stellar image the more dispersion can be employed in the spectroscope, and the users of large apertures therefore do have an advantage in stellar spectroscopic work. But the fact remains that small instruments can be used to very great effect in this field also, provided that one intelligently plans his investigations. I know of no better example of this than one which I am permitted, by the kindness of Father Sidgreaves, to illustrate. Here is a photograph of the spectrum of oCeti, made with a refractor of 4 inches aperture, with a prism of $22\frac{1}{2}°$ angle placed over the object glass. The focal length of the telescope is 4 feet.

The slide shows the spectrum of Omicron Ceti on the 29th November, 1905, and on the 1st December, 1906, and brings out with great clearness the remarkable changes which occurred during that period. If this spectrum had been photographed with such an instrument, let us say, as the Bruce spectrograph of the Yerkes Observatory attached to the 40-inch telescope, there would have been some advantages, but there would also have been some disadvantages, because the entire region covered by the photographs made with that instrument (when three prisms are used) is a limited one here in the blue. All of these remarkable flutings in the less refrangible region would not have appeared in the photographs, and nothing would have been known, if one had been confined with such an instrument to a short *region of* the spectrum, about the very interesting changes shown

in this particular case. The next slide shows another photograph taken by Father Sidgreaves, in this case with a somewhat different instrumental arrangement—a direct vision prism at the focus of a 15-inch equatorial. But you will see the great range of spectrum included on the plate, and remember again that almost all the spectrum, except a very small region, would be missing on photographs taken with such instruments as the Bruce or Mills spectrographs, or other three-prism instruments employed for the investigation of stellar motions in the line of sight. You will notice the remarkably interesting and important fact that the $H\epsilon$ line of hydrogen is absent from the picture, probably, as Mr. Newall suggested, cut out by the absorption of the H line of calcium—the broad H_1 band; perhaps in another star lying nearer to us than the star which gives the bright lines of hydrogen. This serves to illustrate the great importance of the work that can be done with an instrument of very small size indeed, even in this field of stellar spectroscopy, which seems peculiarly to belong to telescopes of large aperture. As I said before, in general the investigator with a telescope of large aperture does have an advantage in stellar spectroscopic work; but there are various investigations of this sort—and of the kind Professor Pickering has taken up in his very extensive surveys of the whole sky with objective prisms—which are of extreme importance, and which can not be carried out with large refractors of great focal length.

I might go on to speak of the possibilities of work on variable stars, but they are familiar to most of you. The observation of many wide double stars, my friend Burnham tells me, has been neglected since the time of Herschel, because the large instruments, and even the small ones, have been devoted to closer objects, so that in revising his great catalogue Burnham had to measure with the 40-inch a great many wide doubles which had not been looked at perhaps since Herschel discovered them more than a century before. Important double-star work is always open to men with small instruments, if a micrometer is available.

Then I might go on to the case where a man has no telescope at all, and still wants to make contributions to astrophysics. I do not now speak of such splendid work as Anderson did when he discovered Nova Persei with the naked eye; but if one were convinced that the overcast sky of London would never open again, he could still work in his laboratory and make important contributions by identifying lines and bands in spot spectra, as Professor Fowler has been doing of late, or by researches in a score of other fields.

I will close with a few practical suggestions. One reference to the matter of atmosphere. Perhaps some of us feel that if we could only ascend into the upper regions we could get results very much better than are obtainable in London. But if we stop to think of the men

who work in London and what they have done, we must recognize the fact that even here the conditions are not so bad as we sometimes imagine. I have often been strongly impressed (since my work in Chicago) with the belief that a smoky atmosphere has some advantages in astronomical work, for it seems that the seeing is frequently improved in solar observations when the sky is smoky. Here is a fine chance to test that question, and I think it has been tested at Greenwich, and that some of the photographs taken there (both solar and stellar) prove that London smoke does not prevent excellent definition. I examined rather carefully some plates there yesterday, and the star images are surprisingly good in many instances. It seems to me that definition by night as well as by day at Greenwich must be of an order much higher than one might suppose when one thinks of Greenwich as being within the boundaries of London.[a] But it is perfectly possible to get good results anywhere, provided sufficient care is taken. One must consider, for example, the best time of day for solar work. It usually happens that the best definition of the sun occurs in the early morning and the late afternoon. Mr. Newall tells me that this is as true at Cambridge as it is at Mount Wilson. This is worth looking into if one takes up work on the sun. Further, one must have a definite plan of work. This is of prime importance. Devote your entire attention to a single investigation, involving, if possible, two or three parallel series of observations, so devised as to throw light on one another. Frequently the value of a given series of observations may be enormously enhanced if other observations are available to aid in their interpretation. For example, in studying the spectra of sun spots, the character of the spots, their motions, and changes of form, and the distribution of the flocculi in their neighborhood, may be vital factors in interpreting the spectroscopic phenomena. Then, again, there is the great possibility that new methods and new instruments can be applied. Up to the present time I think the interferometers of Michelson or of Pérot and Fabry have never been systematically employed for work on the sun. That admirable method which Fabry is using in the determination of absolute wave lengths would perhaps be very useful indeed if applied to the measurement of the displacement of solar lines at the center and at the limb. I also believe that the echelon spectroscope has never been used for the observation of the narrow bright lines in the chromosphere. Furthermore, we are always confronted by the possibility of perfecting our optical apparatus. I have been trying for years to get good prisms of large size, but can not get homogenous glass, and therefore it now seems necessary to attack the

[a] While revising this for republication I learn with great pleasure of the discovery at Greenwich of an eighth satellite of Jupiter.—G. E. H.

problem of fluid prisms. If some one could take that question up and show us how to make very large prisms that would be essentially perfect, they would accomplish a great advance. Lord Rayleigh told me the other day how he made some large fluid prisms that gave nearly theoretical resolution. By an extension of the same methods it seems likely that still larger prisms, suitable for the exacting requirements of photographic work, could be obtained.

And so I might go on pointing out opportunities of various kinds, but I should tire you if I ventured to do so. We must not forget, however, that the possibility always exists of getting some entirely new method that will be quite as important as any application of the interferometer, or the echelon, or other instruments to which I have called attention.

I hope I have shown that it is possible not merely to do work of an inferior quality, but to do work of the first quality, with small or inexpensive instruments; work that can not be duplicated or will not be duplicated with large instruments; in other words, that there is a splendid field for any man who wishes to accomplish results, wherever he may be situated, and however simple his means of research may be. I feel so strongly on this subject that I hope the suggestions I have made will not be entirely without effect. We need the ideas of men from all parts of the world; we need the contributions they can make; and we need them even more than we need larger instrumental means than we now possess.

THE PROGRESS OF SCIENCE AS ILLUSTRATED BY THE DEVELOPMENT OF METEOROLOGY.[a]

By CLEVELAND ABBE.

The ultimate goal of scientific research is not the collection of facts furnished by explorations and surveys, not even the exact data furnished by the most laborious measurements as in astronomy, geodesy, chemistry, and physics. Neither is it the framing of a few generalizations and inductions, such as the general idea of evolution; nor is it the establishment of some isolated fundamental laws, such as the attraction of gravitation, the conservation of energy, the mechanical equivalent of heat, the atomic weights and their periodic law. Research aims to go deeper than all this and show how these laws and phenomena result necessarily from a few simple premises—not premises in the sense of assumption, but axioms that are just as truly the basis of the physical universe as Euclid's axioms are the basis of geometry. These premises or axioms, so far as we can at present see, almost certainly belong to the realm of what we call mechanics, or the laws of force and matter; it may be the mechanics of molecules, atoms, and ions, or it may be the mechanics of solids, fluids, or gases; that is to say, it may be the mechanics of individual molecules, or that of masses of molecules. Moreover, these questions of mechanics always involve some mathematical study—some graphical, numerical, geometrical, or analytical method; in every case the progress of exact science must wait on the progress of pure mathematics.

Owing to the numerous relations between the study of the atmosphere and every other branch of science, meteorology has been from time to time classed as a part of chemistry, physics, geology, and geography, but is now assuming an independence that justifies its recognition as a distinct subject; this fact requires us to explain distinctly of what meteorology consists. It is not a mere description of atmospheric phenomena, neither is it a system of maps and predictions; it is not a popular climatology, nor merely a mathematical

[a] Annual presidential address before the Philosophical Society of Washington, December 8, 1906.

study of the motions of the atmosphere. We must define it as embracing the broadest conceivable study of the atmosphere from any and every point of view; if we subdivide it according to the difficulty of the subject and the extent of our ignorance, beginning with the simplest and passing on to the more difficult portions, we may subdivide it into descriptive climatology, optical and acoustic phenomena, thermal or thermodynamic phenomena, hydrodynamic or mechanical phenomena. The two latter classes of phenomena constitute the subject-matter of the mechanics of the atmosphere and include all that relates to temperature, pressure, winds, cloud, fog, dew, rain, snow, hail, and the daily predictions of storms and weather. It is in the study of these phenomena that the progress of our science has been most conspicuous during the past century; the problems already partially solved involve so much of the most profound modern physics and mathematics that one can not refuse to meteorology a notable place among the most difficult branches of science. Fundamentally, meteorology is the mechanics of the earth's atmosphere; all its other aspects are of minor importance to this and it is our progress in this line of research that should especially claim our attention.

A general historical survey of the methods by which we have arrived at the present state of our knowledge of nature will show that meteorology has passed through the various stages of development that have been common to all the sciences, and that in its present stage of vigorous growth it already stands among those that have progressed the furthest. The methods of advancing our knowledge of nature have been the same in all ages, among all nations, and in almost all individual cases. One individual, or one nation, or one age may differ from another in its predilections for special methods, but in general we find everywhere analogous methods of thought and work, and they even succeed each other in the same order. Beginning with explorations and crude observations, man passes on to generalizations and inductions. If possible he frames speculations or working hypotheses as to the ultimate cause or the rationale of any phenomenon, and then tests his tentative deductions by experimentation until the working hypothesis has been so modified as to represent some general law. The association of several such laws leads to the building up of elaborate deductive theories, not speculations in the popular sense of the word, but well-established systems, or methods of argumentation, that represent a rational and more or less profound knowledge of nature. Such "theories" are well exemplified by Gauss's "Theoria Motus" or Rayleigh's "Theory of Sound."

If at some epoch a man or a nation is unable to apply any one of the above-mentioned methods of study, then the real knowledge of *nature stops at that* point, and man waits until the development of

his powers enables him to take the next step in the line of research. But it has many times occurred that meanwhile men have spent centuries floundering about aimlessly in the bogs of ignorance, following some imaginary light like the will-o'-the-wisp. If dogmatic authority has sometimes hindered the progress of knowledge, still more has man's inherent conservatism, by reason of which he adheres to the teachings of antiquity, the practice of his parents, and the worship of his ancestors. Such conservatism may build up a family or a nation; it may insure the entailment of estates and the power of tyrants, but it is a perversion of the commandment "Honor thy father and thy mother" to doggedly insist that what is good enough for the parent is good enough for the children. The love of truth requires us not only to hold fast that which is good, but to discard that which is false. The path of progress in meteorology is strewn with the wrecks of popular errors.

NATIONAL METEOROLOGICAL ORGANIZATIONS.

Devotion to any science brings with it the formation of special organizations for its promotion, not only private academies, observatories, and universities, but national or state institutions; and meteorology has had its share of these. Of course, these organizations are not always mainly and directly for the benefit of knowledge and science, but more frequently for the material benefit of the people. In America, Henry and Maury; in England, Glaisher and Fitzroy; in France, Le Verrier; in Holland, Buys Ballot; in Austria, Fritsch, were the first to start organized national efforts to make what little we know of the atmosphere available to the practical needs of mankind. Our sister sciences, astronomy, chemistry, and biology, have given us examples of the general principle that neither the people nor their rulers will support scientific research as such, unless and except in so far as the research directly benefits or promises to benefit them. Popular appreciation of science is expressed by the question, "What good will it do us?" This is the inevitable outcome of the strenuous struggle for existence. "Knowledge is power," says one; "Knowledge is money," says another; "Knowledge is fame and position," says a third. Only the few enthusiastic individuals pursue knowledge for her own sake. The majority of the people and even of university students necessarily take the so-called "practical view" of the subject. Appropriations of public money are made in order to obtain results that are of value to the business interests of the whole nation. It remains for the administrative chiefs to decide how much of the time and money at their disposal can profitably be spent on research and how much on daily routine work; therefore the scientific and national organizations have had

quite various experiences. It is within bounds to say that the meteorological offices of France and Germany began with the feeling that we know little of meteorology and must make great additions to our knowledge before attempting practical forecasts; hence in France, under Le Verrier, several years of experience were acquired before that work began. The German office, under Dove and Von Bezold, has thus far restricted itself to climatology and general theoretical studies, wisely leaving it to the new office, just now started, under Börnstein, to attempt predictions for the benefit of the public. The British office, under Fitzroy, stimulated by Glaisher's maps of 1851, began boldly with predictions, but was obliged to modify its plan until further study had shown how to make these more acceptable. The American office has had a happier history, for which we must thank the long-continued preparatory studies and weather maps of Redfield, Coffin, Loomis, and Espy, which continued for forty years from 1820 to 1860, so that we really did know something about the behavior of our special American atmosphere. But especially must we thank the cautious policy of Prof. Joseph Henry and the preliminary daily telegraph maps of the Smithsonian, from 1854 to 1861. In 1870 Gen. Albert J. Myer, favored by an extensive system of telegraph lines, was really justified in attempting to undertake storm warnings based on the daily weather map. Not only has our own Weather Bureau realized all that was hoped for it by its early projectors, but Prof. Willis L. Moore as Chief has now assured it a certain degree of perpetuity by adopting certain principles that insure steady progress for all future time, namely, that behind every high art there stands a higher science; that complete success in weather forecasts demands an equally complete knowledge of the sciences involved in the motions of the atmosphere; that satisfactory progress in predictions can only be based on corresponding progress in our knowledge of the physics that underlies theoretical meteorology.

But you will say that these are only the ordinary axioms of the modern civilized world. True, and it is the recognition of such axioms that marks the domination of the human intellect. The operations of the atmosphere are so obscure that multitudes doubt whether we shall ever understand it and continue to rely on the old-fashioned signs and the annual almanacs. Meanwhile meteorologists throughout the world are seeking to gain knowledge and light from every source; everywhere kites and balloons, mountain stations and cloud observations are being utilized as means of studying the upper atmosphere, while on the other hand each national weather bureau is extending its field of observation horizontally, so as to secure a broader weather map. The insight we get by the help of mechanics, the help we can *derive from mathe*matical physics, the suggestions that we get from

cosmical physics, the new ideas that we get from the laboratory study of chemistry, electricity, hydrodynamics, and radiation, the broadening of our field of observation by the use of wireless telegraphy, all conspire toward the better establishment of our science and consequently the perfecting of the daily predictions.

ELEMENTARY METEOROLOGY.

In every branch of human activity we begin with the simplest ideas and easiest actions, and then progress to the most complex combinations and most difficult constructions, eventually arriving at abstractions of whose essence we know nothing, but whose effects are observable and measurable. This statement applies to all branches of science, and meteorology is no exception. We begin with the direct tesimony of the senses, then we recognize the abstract idea that force must pervade nature and must be the foundation of all the phenomena that we have apprehended by means of our five senses.

The simplest atmospheric phenomena were first observed, and these stimulated the earliest philosophers of classical antiquity. Until most recent times meteorology was not advanced by the work of professional meteorologists so much as by occasional contributions from those whom we ordinarily speak of as astronomers, geographers, physicists, chemists, but who in earlier times were known as philosophers.

To the astronomers we owe certain fundatmental facts, namely, that the earth is a sphere, that it rotates on its axis and revolves about the sun and that its axis is inclined to the ecliptic. To establish these few simple points required two thousand years—from the days of Eratosthenes, born 276 B. C., at Alexandria, down to the time of Copernicus, who died in 1543, and of Galileo, who died in 1642.

To the students of optics we owe the explanation of the twilight, first correctly given by the Arab, Alhazen, who lived in Spain in the eleventh century, but who may have drawn much of his knowledge from earlier Alexandrian Greek manuscripts that are now unknown. But even he knew nothing of the ultimate cause of the refractive power of the atmosphere; he attributed it to the transparency of the air rather than to its density; whereas Kleomedes, A. D. 50, seemed to understand that it is the density of the medium that principally determines the amount of refraction.

The rainbow and its supplementary bows and halos in general were observed more or less accurately in the earliest ages and are mentioned by Aristotle, who knew that they depended in some way upon the position of the sun. The first steps in the proper explanation of the rainbow were taken by Vitellio, who began by observing carefully the rainbows formed in the spray of the waterfall at Viterbo; his work

on optics was written about 1250, but first published by Risner in 1572. The complete explanation had to wait for the development of theories of the nature of light by Newton, Huyghens, Young, and Fresnel; in fact, only within the lives of the present generation have Airy, Mascart, Pernter, and Tanakadate perfected our knowledge of halos and rainbows.

Mirage and the twinkling of the stars were also observed and fairly well described by the early writers in Greece, Italy, and Arabia. Pernter quotes authorities to show that the mirage in the desert, the "Serab," by which the traveler is deceived into thinking that he beholds a distant lake of water, is referred to in many old Turkish and Arab documents and even in the book of Isaiah. The explanation given by the Arabs was to the effect that the deceptive lake of water is due to water vapor or fog floating over the desert; this error continued until Kepler discovered the phenomenon of total reflection of light, which had been independently discovered by Newton and given in lectures as early as 1673, though his "Optics" was not printed until 1704.

The chemical composition of the atmosphere was scarcely suspected or suggested by any of the ancient writers, and we must come down to the days of Priestley, Scheele, and Lavoisier to find anything known on this subject.

The idea that air has physical properties, such as mass or weight, and that it could offer material resistance to bodies passing through it, was often expressed, but the properties were not satisfactorily observed and measured until the days of Galileo in Italy and Stevin in Holland. Galileo, having a pump for compression, was able to show that air is a compressible gas; but having no means of pumping the air out of a receiver, he was unable to entertain the idea of a vacuum, and in fact explained the rise of water in a pump as due to the horror of a vacuum, until his pupil, Torricelli, presented the idea of the elastic pressure of the atmosphere.

Other mechanical properties of the gases of the atmosphere, such as inertia, centrifugal force, expansion with heat, density, elastic resistance, and viscosity, were entirely unknown to the ancients, and were first clearly set forth by Galileo, Torricelli, Stevin, Descartes, Huyghens, Hook, Boyle, and Sir Isaac Newton.

SOCIETIES FOR RESEARCH IN METEOROLOGY.

The association of men into academies or some equivalent organizations dates back to the remotest history. The wise men or learned priests and philosophers of Persia, Assyria, and Egypt were organized in companies connected with temples of worship and as official *astrologers in* connection with the astronomical observatories. The

library and museum at Alexandria, Egypt, founded by the Ptolemies, Soter and Philadelphus, 250 B. C., became the center of the most famous school of science of all antiquity, and developed into a true university, which lasted until overthrown by the Arab Mohammedans. To it we owe Eratosthenes, Euclid, Diophantus, Ptolemy, Synesius, and many other mathematicians and astronomers. The observatory of Ulugh Bey and Tamerlane at Samarkand was for twenty years, 1430 to 1449, a center for the revival of Arabic science, while at the same time in western Europe a revival of knowledge was going on that led Rudolf II to establish at Prague an academy that was distinguished by the presence of Tycho Brahe and Kepler. The modern academy of science, considered as a voluntary association of individuals for the promotion of knowledge, began with numerous establishments in Italy in the middle of the sixteenth century, and meteorology owes almost as much to the three hundred years of activity of the Academia del Lincei, founded in 1603, as it does to the ten years of the Academia del Cimento.

With the invention of the thermometer by Galileo, the air pump by Otto von Guericke, and the barometer by Torricelli begins the modern period of meteorology, when accurate experiments and observations began to be possible. We thus pass from the first crude stages of observation and fancy to the days when every hypothesis was tested by observation—to the days when academies of science became prominent and when the motto of the Academia del Cimento at Florence, "Provando é reprovando," became the watchword of science. This Academy of Experimentation devoted itself to the fundamental problems of physics; it existed only between the 19th of June, 1657, and the 14th of July, 1667; the latter is the date of dedication of its unique published volume, "Saggi," or Reports on the Experiments made by the academy—a volume justly looked upon as the foundation stone of modern experimental physics. This volume was written in the Italian, or popular, language for every one to read easily, and was intended to be the authoritative expression of the conclusions arrived at by nine of the ablest Italian thinkers. The academy did indeed keep a diary showing everything that was said and done by each person in its daily convocations, but the "Saggi" contains no reference to these individuals; it makes public only that upon which all could agree. Galileo, who died 1642, January 8 (n. s.), had been dead twenty-five years, but the spirit that pervades this volume so perfectly represents that which had animated Galileo during his life that, without mentioning his name, these nine students of his reaffirmed and expanded all that he had contended for; so that it has been well said that the "Saggi" reads as though the spirit of Galileo had risen from his grave. The volume was soon translated into Latin and English, and perhaps into

other languages, and exerted a profound influence upon the science of its day.

Although meteorological stations were established in 1657 in Italy, yet academies and societies of persons interested in the special development of meteorology began later with the formation of the Meteorological Society of the Palatinate, at Mannheim, in 1780, followed by the meteorological societies of France and England about 1850; Mauritius, 1860; Austria, 1864; Italy, 1865; Scotland, 1874; Germany, 1883; New England, 1884, and Japan, 1885. Of course all the general scientific societies throughout the world have always included meteorology in some special section devoted to that and cognate subjects.

The progress made since the formation of the Mannheim Society has been entirely in the direction of the line of work that this society laid out, namely, the collecting of data from all parts of the world for the purpose of compiling synoptic daily weather maps for the study of the atmosphere as a whole. It is an instructive illustration of the slowness with which mankind progresses to recall that at the close of the work of the Mannheim Society in 1795 twelve large folio volumes of observations had been printed, and much had been written about the relations between the weather in the different parts of Europe, but, so far as we know, without the actual preparation of a single weather map, although all its data were compiled and published for that very purpose. It was a famous physicist, Prof. H. W. Brandes, of Halle, the eminent author of a work on "The equilibrium and motion of solid and fluid bodies," who, in two dissertations, "Beiträge," or "Contributions to our knowledge of the weather," and "Repentinis," "A physical dissertation on the sudden variations observed in atmospheric pressure," Leipzig, 1820, finally drew from these ponderous volumes the data for a series of maps showing the circulation of winds around areas of low pressure, and thus opened the way for the study of the mechanical problems involved in storms. It must be confessed, however, that his work did not greatly affect the trend of thought in those days; it was too early for Germany to be able to take advantage of his teachings. Nevertheless, as the principal editor of the most famous encyclopedia of physics, he filled the first few volumes of Gehler's Physikalisches Wörterbuch with the most advanced knowledge of his day. The sixth volume of that work, published at Leipzig in 1837, contains an article on meteorology written by Muncke after the death of Brandes, in 1834; therein Muncke relates of himself and Brandes that in 1820 they had developed a plan (that had to be given up on account of wars between Italy and Spain) for the publication of a general European journal of meteorology, in which Muncke should devote himself to the southwestern half of Europe, *but Brandes to* the northeastern half. Twenty-four principal sta-

tions were selected, between Sebastopol and Lisbon, Christiania and St. Petersburg, for which they were to publish monthly tables of the individual daily readings of all meteorological elements, and to which they proposed to add every notice that could be obtained relative to the weather on those same dates for North America, East Indies, and other distant parts of the globe. Muncke remarks that this plan was rather gigantic, but it responded to the recognized fact that science was covering a broader field and that international works such as those on the measurements of degrees, observations of gravity, and voyages of discovery were already recognized as necessary. In fact, only in this way can meteorology attain to a solid basis, and it is necessary that the scientific public should be able to compare observations made at widely distant places; for the works above mentioned by Brandes had already shown that the causes upon which depend the existence of the storms in western Europe must be sought for over the Atlantic Ocean. Muncke concludes by saying: "Time will show whether the nations of Europe already so intimately related to each other will by mutual business arrangements support such a meteorological union to the furthering of the general peace of the continent." Since the days of the Palatine Society and its active secretary, Hemmer, there never has been any doubt that a union of all the nations of the globe must be effected before we shall be able to do justice to the fundamental problems of meteorology and climatology. To this society and to Hemmer and Brandes, Germany owes her right to the claim of having taken the first steps toward the study of dynamic meteorology.

Simultaneously with Brandes, but undoubtedly quite independent of his work, the leaders of American meteorology—Redfield in New York and Espy in Philadelphia—began a life-long series of studies, at first on the geometrical and afterwards on the kinetic relations of winds to storms, and of storms as a whole to the adjacent atmosphere. The United States Army Medical Corps, the United States Land Office, the regents of the University of New York and several States organized systems of reports to which the Smithsonian eventually succeeded.

These organizations were primarily for the study of climate, but in 1842 Espy was appointed "Meteorologist to the United States Government" and with that date began our national organization of cooperation with him and the Smithsonian Institution in the study of American storms. Between the theoretical cyclonologists and those who adhered more closely to the records of observations active discussion continued from 1820 until 1870, and prepared all thoughtful minds to receive the more correct views of the next generation of students based on the study of daily weather maps.

THE CONSTITUTION AND PROPERTIES OF THE ATMOSPHERE.

To the chemists and physicists meteorologists owe a long series of researches on the constitution and properties of the atmospheric gases. This work may be said to have begun with Boyle next after the less important work of European alchemists. Galileo had shown that the air has weight. Otto von Guericke had so constructed his first air pump (as shown by the pictures, although he himself does not say so in words), that the *heavy air should flow down* and out of the vessels from which he would pump it as he pumped water. But it is to Boyle that we owe the idea that there is an elastic spring in the air, and also that the air is a complex combination of several different vapors, such as those that produce rust and those that are exhaled from the earth, the water, vegetables, and animals. Indeed, the springiness of the air excited his suspicion that there might be some vital substance diffused through the atmosphere. The experiments that he proposed to have made—that he in fact began, and that were carried out by his contemporary, John Mayow—bore on respiration, oxidation, and evaporation as the sources of new kinds of air.

Boyle was the first to suggest that the atmosphere consisted of air, properly so called, and water in a state of expansion, together with other gases that emanate from the earth and exert an injurious influence on the health. De Saussure seems to have been the first to measure the absolute quantity of aqueous vapor in a given volume of atmosphere. In 1760 Lord Cavendish showed that the vapor evaporating from water in a vacuum had a definite elastic pressure, which he measured at several different temperatures.

The temperature of the dew point seems to have been first observed by Le Roy (1750), Dalton (1800), and Daniel (1820). The psychrometer, or wet and dry bulb thermometer, is generally ascribed to August (1825), but the wet bulb was used long before by Beaumé; it was August who gave us an acceptable, rational theory of its action, while at the same time, and quite independently, Ivory in 1822, Espy in 1829, Belli in 1830, and Apjohn in 1834, introduced modifications, all of which are now combined in Ferrel's, Grassman's, and other theories and tables for the whirled psychrometer. The relative humidity was first observed by means of a catgut hygrometer by Brander (1650), but the hair hygrometer of De Saussure (1780) and his persistent researches to improve it were the first steps in modern hygrometry.

The discovery of carbonic-acid gas, or fixed air, is generally attributed to Joseph Black, of Edinburgh, who, however, had several predecessors less widely known. In 1752 he discovered that this gas is the same as choke damp, or fixed air. According to Ramsey, *Black* showed that the common air of the atmosphere contains a

small amount of fixed air. The next step in the separation of the gases in our atmospheric mixture was due to Rutherford, a pupil of Black, who in 1772 announced the discovery of nitrogen as the residual gas after the combustion of carbon and the absorption of the resulting fixed air. The discovery of oxygen was made independently and nearly simultaneously by Priestley and Scheele; but Priestley published his results in 1775, a year before Scheele. The recognition of oxygen as an independent gaseous element and the establishment of our modern view of the air as a simple mixture is due to Lavoisier, who published several memoirs on the subject in 1777 and 1778, while Cavendish was carrying on a parallel system of experiments in England, experiments that he began in 1777, but published only some years later.

With the discovery of nitrogen and oxygen in the atmosphere and the measurement of the exact ratios of these and various so-called impurities, the chemistry of the atmosphere halted until, in 1882, Lord Rayleigh began a research on the relative densities of hydrogen, oxygen, and other gases, concluding in 1893 by the statement that nitrogen obtained from the atmosphere was somewhat denser than nitrogen prepared from ammonia, and that the difference, though slight, was so far beyond all question that it demanded an explanation. This explanation was announced in a preliminary way in August, 1894, but was received with such incredulity that one chemist sarcastically inquired "whether the *name* of the new gas had also been discovered." But the matter was brought to a clear demonstration by diffusing the mixed gases slowly through a long train of tobacco pipes of the variety known as the "church-warden pipe," which is made of a very fine clay through which diffusion proceeds very slowly. Thus argon was discovered. Of course you will recognize the fact that this last step in the analysis of atmospheric air is not a chemical but a physical process, illustrating the general statement that no one branch of science can endure or progress without the assistance of correlated friendly branches.

The discovery of argon paved the way to new ideas in regard to the structure of the molecules of gases, ideas that threaten entirely to undermine some portions of the old kinetic theory of gases. Since the discovery of argon, chemists and physicists, working long different lines, have, as you know, devised methods of producing extremely low temperatures; so that atmospheric air, and even hydrogen, have been liquefied, and by the help of these extremely cold liquids other gaseous constituents have been discovered in the atmosphere. First, *helium* was discovered by its lines in the solar spectrum; then it was evolved from a rare mineral, named cleavite, and finally it was shown to be present in our atmosphere. Then a large mass of air was cooled down to its boiling point, and in the residue

krypton was discovered. Finally argon was also cooled down to its boiling point and *neon* was discovered. The separation of neon from helium requires the very low temperature of boiling hydrogen, or 20.5° on the absolute scale. Although these new gases occur in our lower atmosphere only in very minute quantities, yet there is some reason to believe that eventually they will play an important part in explaining some of the electrical phenomena that are at present quite mysterious. It has been independently suggested by Huggins and Schuster that the brilliant green line in the spectrum of krypton is probably identical with the green line in the spectrum of the terrestrial aurora borealis, showing that krypton may exist in our upper atmosphere or in the adjoining celestial space.

But we have not finished with the gases of our atmosphere, for in 1898 Madame Curie announced the isolation of two new substances, polonium and radium. These furnish an emanation, which consists of gaseous particles, among which is helium, which latter also emanates from the element thorium. Numerous other substances are now known to send out such emanations, each of which resembles some of the inert gases of the atmosphere. It seems probable that these emanations represent the degeneration of molecules of the complex elements into simpler molecules or even into elementary matter, if such there be, thus leading to a great expansion of our ideas as to molecular structure. As these emanations are also accompanied by an ionization of one or more of the atmospheric gases, it results that the electrical properties of our atmosphere depend in some way upon them. In general, therefore, this brilliant chapter in the history of research is another illustration of the dependence of meteorology upon the progress that is being made in every other branch of science. So we have now to face a new problem in evolution. Laplace taught the evolution of the solar system from a gaseous nebula; Huxley taught the evolution of higher forms of life from elementary structures; who will now teach us the evolution of the gaseous molecules of the atmosphere and the solid elements of the earth, from the initial atoms, corpuscles, or electrons?

MECHANICS OF THE ATMOSPHERE.

Dynamic meteorology deals essentially with the study of the behavior of a true gas, dilatable with heat and compressible with pressure, but mixed with small and variable percentages of vapors that condense to liquids or solids at ordinary low temperatures. The problems of modern meteorology therefore lie in the field of aërodynamics and thermodynamics, and can only be solved in proportion as our knowledge of experimental physics shall be extended. But the *proper* treatment of these problems also involves the application of

difficult branches of mathematics and analytic mechanics, and these subjects have not yet been developed to an extent sufficient to handle any but the simplest of the problems of nature.

As we read the scientific literature of the eighteenth century we find Euler, in his "Mechanics" (1736), developing the fundamental formulæ for the movements of dry gases and ideal liquids, after he had proceeded as far as he could with the mechanics of rigid bodies. In his prize essay of 1746 D'Alembert developed a theory of the winds. We pass then to the great French mathematicians, Lagrange, Poisson, and Laplace, and the English mathematicians, Green and Stokes, to all of whom we owe investigations of the laws of motions of fluids under two essentially different conditions, namely, when a velocity potential exists and when it does not exist. In 1851–1855 appeared the memoir of Stokes on viscosity and in 1857 the famous memoir of Helmholtz on vortex motions, each of which removed difficulties that had hitherto obstructed our progress. The works of Sir William Thomson, now Lord Kelvin, on thermodynamics and on circulatory motion, and the persistent researches of Bjerknes, father and son, in the application of vector analysis, have clarified our ideas and represent our present highest attainments in this branch of mechanics. Just as meteorologists have hitherto been dependent upon physicists for the apparatus with which to observe, and upon the mathematical physicists for the explanation of the optical and thermal, the acoustic and the electric phenomena of the atmosphere, so now they are coming to be more and more dependent upon the higher mathematicians to resolve the analytical difficulties inherent in the complex problems of fluid motion.

It is very rarely that the meteorologist arrives at a phenomenon deductively and then examines the records of observation to see if it actually exists. Ferrel did this in a few cases; but usually we have proceeded by slow inductive methods. For instance, the Phœnician voyagers and the Greeks who penetrated into India knew of the existence of the southwest monsoon, but a complete knowledge of its origin and nature has required centuries of observation and the labors of men of great talent in mechanics. Fifty years ago it was assumed in a general way that the heated air over the interior of Asia, by expanding and overflowing, gave rise to an indraft corresponding to the sonthwest monsoon; but it remained for Ferrel, about 1880, to show that it was not merely a heated interior, but a heated high plateau that was necessary to produce this great current; and it was not until 1890 that Sir John Eliot showed that this monsoon current is by no means a simple disturbance of the northeast trade winds that are appropriate to the latitudes of India, but that we have to go much farther south, far across the equator, and see that the whole southeast trade-wind system of the southern Indian Ocean is perverted from

its course. Instead of rising in the torrid zone and turning back upon itself to Antarctic regions, the southeast trade rushes across the equator, skirts the coasts of Africa, Arabia, India, Siam, and China, whirls around the great desert plateau of Tibet, producing the area of low pressure that is central over that region in the hot months, and finally is lost in Kamchatka. Of course this transfer of a great mass of air from the southern to the northern hemisphere during our summer must be followed eventually by the return of an equivalent mass to the southern hemisphere; but we have not yet discovered how, or when, or where that return is effected. Therein lies the secret of much of our so-called periodic or quasi-periodic and secular weather changes which depend on the internal mechanism of our atmosphere, not on solar or cosmic influences.

Finally, we now go one step further and note the fact that we may divide the surface of our globe into two hemispheres, known as the continental and the oceanic. The former has its pole on the Greenwich meridian at about 30° north, including nearly all of Europe, Asia, Africa, the Atlantic Ocean, and both the Americas, being about three-fourths land. The other has its center about 40° south, includes the greater part of the Pacific, Indian, and Antarctic regions, and is four-fifths oceanic. The sun's heat pours upon the continental hemisphere with especial fervency in May, June, and July, and upon the oceanic hemisphere in November, December, and January. The circulation of the air, both horizontal and vertical, the distribution of temperature, moisture and pressure, the resulting winds and rains over the continental hemisphere in its summer have but slight analogy with the corresponding phenomena over the oceanic hemisphere in its summer, because of the differences in the action of insolation upon land, water, and snow or ice. We are no longer justified in treating the whole atmosphere as though it were resting upon a globe of uniform surface and subject to slight perturbations by reason of ocean currents and small continents. We have to consider the insolation of the continental hemisphere and that of the oceanic hemisphere as two disturbing forces of equal magnitude, acting on the air above these in such a way as to cause these halves of the earth's atmosphere to react on each other in a series of movements or perturbations most delightful to contemplate and most inspiring to the mathematical expert, who quickly acquires a grim determination to solve the problems that are presented. This interaction of the continental and oceanic hemispheres is responsible for the fact that what happens in India in its summer by reason of the special character of its monsoon is not only related to what happens in Africa and Siam, but even to what happens in Australia and America. A most interesting evidence of the recognition of this principle will be found in the fact that Mr. Gilbert T. Walker, the

meteorologist of the Indian service, in his annual forecast of the Indian monsoons, makes a statement of the conditions affecting the monsoon rainfall in which he includes the precedent conditions over Australia, South America, and Siberia; he shows that the Asiatic and equatorial regions, taken by themselves, do not suffice to determine the future character of the monsoon.

A corresponding indication of the broadening of our field of view is found in the fact that our own Weather Bureau has lately begun to receive telegrams as to the barometric pressure prevailing in the interior of Asia, more especially in Siberia, under the conviction that the oscillations that take place in that region give some indication of what will subsequently occur in our own territory. These ideas developed at once from our experience during the first year of our forecast work in 1871, and led promptly to the establishment of our "Bulletin of International Simultaneous Meteorological Observations" with its daily charts of the northern hemisphere, undertaken by Gen. A. J. Myer in 1873, in accordance with our idea that the atmosphere must be studied as a unit. His published bulletin of international observations gives us a daily map of the whole northern hemisphere from 1875 to 1884, after which only monthly maps were published. But the daily manuscripts have continued to be compiled up to the present time, although on a somewhat different plan. These afford valuable material for working out the relation between atmospheric movements on a large scale. The first steps in such generalizations were taken by Professor Garriott, to whom are due the conclusions given in 1891 in "Weather Bureau Bulletin A, Summary of International Meteorological Observations."

Next we come to a series of charts published by Hildebrandsson about 1895, showing the simultaneous departures in pressure at many stations over the whole globe. These tables and charts show that an excess or a defect of pressure may be observed simultaneously over a very large part of the globe, perhaps one-half or even three-quarters of its surface, while in other months the conditions will be nearly reversed. Inasmuch as he took monthly averages, he was not able to show the progressive movements of these areas of high and low pressure, if, indeed, they do move, as is fair to presume and as he would probably have discovered if he could have compiled daily or pentadic instead of monthly maps.

Hitherto our observations have been largely confined to the earth's surface and to stations near sea level; but we must go higher in the atmosphere. The importance of mountain stations and of balloon work was recognized a century ago, as shown by the establishment of several mountain observatories and by the early balloon voyages of Barral and Bixio and their successors. The numerous voyages by Glaisher added greatly to our knowledge, but the systematic work

with both balloons and kites since 1893 has constituted a brilliant epoch in our study of the atmosphere. Although the kite had frequently been used by Franklin and other electricians during the previous forty years, yet its use to carry thermometers to great heights dates only from Alexander Wilson, of Glasgow, 1780. A century later it was employed in England to study the upper winds by E. D. Archibald. The invention of the Hargrave or box kite and the improvements introduced in every detail by Professor Marvin, and to a less extent by others, have converted the kite into a most important meteorological apparatus. Meanwhile the use of a small balloon carrying only self-recording instruments has been perfected by Teisserenc de Bort, of Paris, and Assmann, of Berlin, until it largely replaces the manned balloon; and as it can ascend to greater heights, it becomes our most powerful apparatus for exploring the upper atmosphere. At present the limiting height attained by kites is about 20,000 feet and by sounding balloons, so called, 25,000 meters, although these limits are only attainable under the most favorable circumstances. The persistent use of kites at Mr. Rotch's observatory at Blue Hill and the development of the mathematical theory of the kite by Professor Marvin stimulated all European observers to undertake the same line of research, each in his own country. Mr. Rotch has also been successful in securing the cooperation of Teisserenc de Bort for special kite explorations over the ocean. With characteristic energy, Assmann has been able to send up either a kite or balloon, or both, every day—first at Berlin, 1899–1902, and afterwards at his new observatory at Lindenberg; so that we have a continuous history of the temperature of the air above Berlin for several years, up to the highest points attained by kites and balloons.

On the other hand, in the United States, the Chief of the Weather Bureau, after authorizing Professor Marvin to develop the kite, the reel, and the meteorograph, established seventeen kite stations north of a line joining Washington and Topeka, as a southern limit, with the intention of receiving the reports by telegraph and compiling a daily map of the conditions in the upper atmosphere. The work at these stations extended from April to November, 1898. The average results as to vertical gradients of temperature, humidity, and wind were compiled by Doctor Frankenfield (see Weather Bureau Bulletin F), but the preparation and study of a daily map of the upper atmosphere analgous to the maps that we are accustomed to use at the sea level required a new line of thought for which the world was not quite prepared at that time. To this problem Prof. C. A. Bjerknes, of Stockholm, has paid especial attention, and his ideas have been embodied in a memoir prepared by his pupil, J. W. Sandstrom (published by the American Philosophical Society in 1904), elucidating *the first steps* proper to be taken in the reduction of the observations

with balloons or kites to any given level in the atmosphere. These authors make the point that as the surface of the ocean is an equipotential surface, therefore observations reduced from it upward to some other equipotential surface of gravity possess simpler relations to each other than when reduced to a uniform height above sea level. With the help of the Carnegie Institution, Bjerknes and Sandstrom are now still further developing and improving their method with the assurance of throwing new light upon atmospheric motions.

Even when we study the motions of gases on a small scale in our laboratories, we have the greatest difficulty in understanding the processes that go on right before our eyes; still more is this the case with those that go on in the atmosphere. The smooth flow of air, like that of water, made visible by some fine floating particles, suddenly changes without apparent cause into a series of whirls and vortices, and then from whirls back to a steady, smooth flow. A vortex ring of air traverses a large room to a distance far greater than a fine straight jet can do, as though its large front surface experienced less resistance than that of a small jet.

Under hydrodynamics proper I may mention the names of Chree, Bigelow, Bjerknes, J. J. Thomson, Ekholm, Margules, Wien, Shaw, and Rayleigh; also the discussion between Airy, Ferrel, Wien, and Kelvin as to the tides in the atmosphere, resting on the interpretation of a certain formula in the memoirs of Laplace, a subject that was finally elucidated by Doctor Ling, of Columbia University. Not only do we owe the mathematical theory of heat to Fourier and Poisson, but especially to the former a posthumous memoir on the motions of fluids in which the internal motions and the distribution of heat are mutually interdependent. This memoir is but a fragment, establishing certain differential equations, the solution of which is rarely possible when the boundary conditions are given; so that in general we must at present rely upon partial solutions and suggestions derived from experiments or observation. To Rayleigh and Stokes we owe a number of memoirs on fluid resistances, including the first solutions of problems involving viscosity or internal friction of fluids. To Prof. Joseph Reynolds we owe some beautiful experiments showing how the motion of a fluid changes from a laminar flow to a vortical flow whenever the excess of internal energy amounts to a very small limit, and vice versa.

To Willy Wien, a pupil of Helmholtz, we owe the development of problems relating to vortex and wave motions in the earth's atmosphere. To Professor Pockels, another pupil, we owe a very ingenious memoir on the influence of mountain slopes in forcing moist air to ascend and form clouds and rain. It is the presence of aqueous vapor in our air and the consequent thermodynamic complications that necessitates a combination of hydrodynamics with thermodynamics

and leads to still more complex mathematical problems, whose solution is absolutely necessary if we would understand the formation of clouds and rain. In this branch of study we have an instructive memoir by Brillouin, in which he is able to explain in a general way the formation of many types of clouds or layers of clouds as due to the mixture of masses of air having different degrees of temperature and moisture. The appearances of the clouds have been most carefully observed and recorded for two centuries, but the ability to learn what they can teach us has only become possible within the past thirty years.

The first step in the application of thermodynamics to meteorology was undoubtedly taken by Espy in 1822, when he stated that the cooling due to the expansion of air ascending into regions of lower pressure caused the formation of clouds and the lower temperature of the air of the upper strata. However it was soon found that the cooling is not due to the expansion as such, but to the *work* done by expansion against atmospheric pressure. This general explanation was accepted by French physicists in 1839, but was given greater precision by Sir William Thomson in 1864, and Peslin in 1869; it was satisfactory to American, English, and French students, but seems not to have been accepted in Germany until Professor Hann wrote an explanatory article in the Zeitschrift of the Austrian Meteorological Society for 1874, showing how the laws of thermodynamics apply to the atmosphere. This paper was followed by much more elaborate studies and a series of valuable publications by others, so that it is now easy to apply our knowledge of thermodynamics to the atmosphere. A most helpful memoir along this line was that by Hertz, in which he gave a very simple diagram (known everywhere as the Hertzian diagram of adiabatics for the atmosphere) for determining what the condition of moist air must be on attaining a given height in the atmosphere. Assuming that it retains its original amount of heat during the whole time, his diagram shows very clearly the results of the ascent of ordinary clear air up to a level at which cloud formation begins; then to the level at which the precipitation is in the shape of frozen water drops, or hail, and above that to the region in which precipitation must be in the shape of icy spiculæ, or snow. These four stages of cooling, viz, the dry stage, cloudy stage, ice stage, and snow stage, characterize nearly all the important phenomena of the weather.

In his further applications of thermodynamics Professor von Bezold has clarified our ideas by introducing a series of diagrams after the manner first taught by Clapeyron. Assuming that a unit mass of air mixed with a given quantity of moisture rises or falls adiabatically, his diagrams then show its condition at any moment by means

of curves analogous to those used by the steam engineer when he wishes to ascertain the condition of the steam in his cylinder and the amount of work being done by it. Von Bezold also shows how to treat any changes in the air that are not adiabatic, although so nearly so that they can be called pseudo-adiabatic. Lately a student of von Bezold, Doctor Neuhoff, has published a modification of Hertz's diagram, together with elaborate tables, by means of which most problems in the formation of cloud, rain, and hail or snow may be very easily solved, and with as much accuracy as the present state of our knowledge allows. A still more extensive work along this line has been published by my colleague, Professor Bigelow, in his Weather Bureau Report on International Cloud Observations. He has not only discussed all the observations of clouds made in connection with the International Programme during the year 1896–97, but has added to this a memoir that is quite unique in meteorology, including a complete system of fundamental constants, formulæ, and reduction tables. I need only add that my colleague's work on the hydrodynamics and thermodynamics of terrestrial meteorology as contained in this volume will undoubtedly be recognized as perfectly sound. By collecting all important formulæ and numerical constants into one system of tables with uniform notation, he has simplified the work of young students and rendered it convenient for anyone to rapidly survey the increasing literature of the subject. I especially commend his chapters 10 and 11 to experts in mathematical physics. He has arranged his numerical tables so as to make them as convenient for the solution of his problems as are the diagrams of Hertz and Neuhoff.

THE WATERSPOUT OF AUGUST, 1896.

Nothing will more brilliantly illustrate the success with which our colleague has attacked atmospheric problems than his latest memoir, which is now being published in the Monthly Weather Review on "The Waterspout of August, 1896," about which I will say a few words. The lantern slide pictures that I am about to throw upon the screen are exact reproductions, without retouching, of photographs of this spout, which occurred on Wednesday, August 19, 1896, in Vineyard Sound, Massachusetts. It was fortunately photographed or accurately observed from at least six different points south, southwest, west, and northwest of the spout itself, the principal views being those taken at Cottage City, on Marthas Vineyard, which was about 5¾ miles southwest of the track of the spout. Fortunately a small schooner was passing along between Cottage City and the spout, and as the views always include this vessel its movement became the means of measuring the exact intervals of time. In order to derive the best results from these photographs, Professor Bigelow personally

visited the location and made sufficient measurements to enable him to convert the apparent distances given by the photographs into angles and linear distances; so that we are able to chart the position of the schooner and the waterspout from time to time during the twenty-five minutes embraced by the photographs. Three spouts were seen in succession, though it is probable that there was only one general whirl in the atmosphere, moving slowly southeastward while the spout cloud appeared and disappeared. No photographs of its first appearance were obtained, but those of the second and third appearances are published as half tones in the Monthly Weather Review for 1906 and are numbered as follows:

Second appearance:

A, 1.02 p. m., by Chamberlin at Cottage City.
B, 1.03 p. m., by Coolidge at Cottage City.
C, 1.08 p. m., by Hallet at Cottage City.
D, 1.12 p. m., by Dodge at Vineyard Haven.
E, 1.14 p. m., by Ward at Falmouth Heights.
F, 1.17 p. m., by Coolidge at Cottage City.
G, 1.17 p. m., by Coolidge at Cottage City.

Third appearance:

A, 1.20 p. m., by Chamberlin at Cottage City.
B, 1.24 p. m., by Chamberlin at Cottage City.
C, 1.27 p. m., by Coolidge at Cottage City.

By reducing the measurements made on the photographs to linear dimensions Professor Bigelow arrives at the following figures, which will interest you, because they are certainly the first that have ever been determined accurately for any waterspout:

The diameter of the waterspout at sea level was 240 feet; its smallest diameter midway between this and the cloud, 144 feet; at its summit, or the lower surface of the cloud, the diameter was 840 feet. The approximate length of the tube, or height from the ocean to the lower surface of the cloud, 3,600 feet. The height of the top of the cloud above its own base was 12,400 feet, and its total height above the ocean level was 16,000 feet. The spray, or cascade of drops forming a cloudy or smoky appearance at the base of the spout, was 720 feet in diameter, and the height of the summit of this cascade was 420 feet.

As a small vessel is visible in the middle of some of these pictures, I will add that the distance from the photographic camera at Cottage City to the waterspout was 5.75 miles, but the distance to the schooner was only 2 miles; the movement of the waterspout from the northwest to the southeast was at the rate of about 1.10 miles per hour; the rate of the schooner was 1.7 miles per hour. The wind was very light at the time, as stated by several observers and as shown by the smoothness of the water. Meteorological observations are rather *anty*, but from the best information at hand Professor Bigelow

finds the average temperature of the air at sea level at the place of the spout was 67.5° F., or the maximum for the day, and the thermograph for Nantucket also shows that the spout occurred at the time of maximum temperature. On the other hand, the temperature at the land stations fell rather rapidly to 56.5° at Vineyard Haven and 59.0° at Woods Hole, so that the effective temperature within the anticyclonic wind that prevailed around the outside of the cloud, or at a distance from the spout, was about 58°. The barometric pressure in this outside region was about 30.10 inches, but it must have been about 30.05 near the waterspout. The relative humidity was low at the meteorological station. The lower strata of the atmosphere were drier than on any other day of the month, and after several trial computations Professor Bigelow accepts a relative humidity of 64 per cent as prevailing in general near the surface of the water at the time the waterspout was formed. These are the meteorological data at sea level beneath the cloud which surmounted the waterspout. This cloud was a large cumulo-nimbus, with its flat base about 3,600 feet above sea level, as just stated in connection with the length of the tube. With these meteorological data and the thermodynamic equations, Professor Bigelow computes the conditions in the air ascending in a rapid whirl within the center of the tube.

The preceding dimensions, computed trigonometrically, have been quoted as measured from the photographs, but the figures deduced from thermodynamic theory and Professor Bigelow's tables are as follows: The height of the base of the cloud, or the dry stage of the ascending air, should be 3,537 feet, or 63 feet less than the 3,600 measured on the photograph. The cloud stage extends thence upward for 5,669 feet, or to a total height of 9,206 feet. Here the freezing or hail stage begins, which is a comparatively thin layer of only 243 feet, and therefore ceases at a total height of 9,449 feet. Above this all precipitation is in the shape of snow, or minute crystals, certainly not hail or frozen water drops, and the thickness of this layer, 6,765 feet, brings us to the top of the cloud, at 16,214 feet, or about 5,000 meters above sea level. The agreement of these thermodynamic computations with trigonometrical measurements is quite satisfactory.

Now the motion of the air depends essentially upon the change of pressure, or the gradient. An abnormal horizontal gradient will produce horizontal motion or whirlings, but a vertical gradient will produce rising or falling motion of the air. Only a short distance from the waterspout, over the island of Nantucket proper, the vertical gradient corresponded to a fall of 0.098 inch for each ascent of a hundred feet, whereas the temperature and moisture conditions over the water near the *spout* give a vertical gradient of 0.101 inch per

hundred feet. This small difference of 0.003 inch per hundred feet corresponds to a total difference of 0.11 inch between sea level and the cloud base 3,600 feet above. It is this difference of pressure that is the effective gradient for vertical movement, causing the air at the outer boundaries to slowly descend while the air within the tube rapidly ascends.

The main part of Professor Bigelow's memoir is devoted to explaining numerically each step in the formation of the spout and its linear and vertical motions over Vineyard Sound. From this special study he is led to investigate the whole question of the condition attending any overturning that may occur in the atmosphere. If a layer of cold air be spread over a layer of warm air, resting quietly upon it with the help of an intervening diaphragm, and the latter be removed, we all know that the cold air must descend and the warm air rise—a process of overturning such as is occurring every day in the atmosphere. The mechanical conditions or mechanical theory of this upsetting were recently worked out by Margules, and his views, with some important modifications, are developed by Professor Bigelow in such a way that a certain conclusion is inevitably reached. This overturning takes place not merely in a small way, as in thunderstorms, but on the grandest scale in tropical hurricanes. Now the question has been discussed pro and con for a hundred years as to whence comes the energy involved in the production of the rapid rotary winds of hurricanes. Espy maintained that in thunderstorms this energy was derived from gradients due to the condensation of aqueous vapor and the evolution of heat in the clouds. I thought it due also largely to the sun's heat acting on the top of the cloud. Professor Bigelow shows that while these are true causes, yet for hurricanes they are entirely insufficient, and that the energy of these great storms is mainly derived from the gradients produced by the overturning of layers of cold air flowing from northern latitudes over the warm air that is flowing from southern latitudes; by the descent of this cold air to the ground the force of gravity gives it great velocity and momentum. In other words, we must not look upon a great storm as a symmetric cyclone with a center of warm rising air and an inflowing pericyclone of cold air, as was taught by former meteorologists, but we must face the problem of a simple overturning in the lower strata of the atmosphere below the level of the general west wind that is flowing a few miles above us. The ideal cyclone and anticyclone probably do not exist in the atmosphere. This conclusion gives precision to an idea that Ferrel fully acquiesced in, namely, that the atmosphere has no simple circulation, cyclonic or anticyclonic, but is a complex *mass* of interlacings of currents; so that the progress made by him-

self in studying ideal types must sooner or later be replaced by researches that adhere more closely to the actual phenomena of nature.

CONCLUSION.

The resolution of problems bearing on the mechanics of the earth's atmosphere is stimulating the efforts of the world's best men, and illustrates the stage to which meteorology has attained in its progress toward being an exact science. Some portions of meteorology are already as exact as our knowledge of chemistry, optics, physics, or astronomy can make them; other parts are still in an unsatisfactory condition, which, of course, is also true of every branch of knowledge. We must congratulate our colleague, Professor Bigelow, on the contributions that he has made along lines of research that will help the next generation of students to a more thorough knowledge of laws that will eventually become the basis of satisfactory long-range forecasts. It will always redound to the credit of the Weather Bureau to have encouraged and published such work as his in this difficult field.

Equally creditable to America is the conception and establishment by the Chief of the Weather Bureau of a special research observatory at Mount Weather, where for the first time in the history of meteorology the researcher has been separated from the observer, and a special institution provided for him. This seems like the realization of an idea contained in a paragraph in my address at Indianapolis in 1890: "Why found new colleges and universities to teach what is already taught elsewhere? *Exploration is the order of the day.* Give us first the means to increase knowledge, to explore nature and to bring out new truths. Let us perfect knowledge before we diffuse it among mankind, so that what we teach may with every coming year be nearer and nearer the eternal truth of God's creation."

This exhortation is as applicable to-day as then. Meteorology is not yet properly recognized in our colleges, nor as a postgraduate course in our universities. The science has progressed, but the universities have not kept up with it. Laboratories have been provided for chemistry, physics, psychology, wonderful observatories for astronomy and elaborate establishments for mechanical engineering, but a laboratory for the experimental study of the motions of the atmosphere has not yet been provided, although the men who could conduct it are ready and anxious to begin the great work that they see before them.

new geology would have nothing to do with the search for cosmogonies and such like fancy foods, and the Geological Society of London should be nourished on unadulterated facts.

The time was ripe for the change. No less a person than Goethe, once an enthusiastic votary of geology, was now, in his play of "Faust," holding up its teachers to ridicule. The theories "evolved from the inner consciousness" of continental Neptunists and Plutonists were to Goethe excellent subjects for caricature. It was then the Englishman, Greenough, founded a society to turn geology from the pursuit of fleeting fancies and lead her to the study of sober but enduring facts. The members of this society were to abandon the quest of scientific chimeras; they were to leave to later generations the attempt to solve the universe as a whole.

The Geological Society has owed its influence to its bold, original purpose. It was not founded as a drifting social union of men with a common interest in a single science. Its object was to apply to geology one particular mode of research. It adopted as its motto this fine passage from Bacon:

"If any man makes it his delight and care—not so much to cling to and use past discoveries, as to penetrate to what is beyond them—not to conquer Nature by talk, but by toil—in short, not to have elegant and plausible theories, but to gain sure and demonstrable knowledge; let such men (if it shall seem to them right), as true children of knowledge, unite themselves with us."

The methods of the society were as practical as its ideals. London, with characteristic unconventionality and originality, has used its scientific societies as its university for post-graduate teaching. Informally the Geological Society enrolled every British master of geology on its staff of unpaid professors, then set each of them to teach the branch of geology which he knew best. And these professors were no carpet knights; they were knights errant who derived their knowledge, not from books alone, but from their wanderings over hills and dales, in mines and quarries, by ice-polished rocks and water-worn valleys. At its meetings the leaders of the society announced what they had discovered, gave sure and demonstrable proofs of their discoveries, and showed in what direction the geological forces should be directed for the conquest of Nature. The goodly fellowship of the Geological Society has always encamped on the ever-advancing frontier of geological knowledge, where the well-surveyed tracks pass out into the bright, alluring realms of the unknown.

The actual founders of the Geological Society were apparently men of less showy intellect than the great Werner, whose teaching had intoxicated many of the most gifted of his enthusiastic pupils. They were men, like Horner and Greenough, who had a practical insight *that* enabled them to give a permanent help to the progress of science.

They had that supreme gift, the power to see things as they are. It would not be fair to claim for them that they were the originators of accurate methods in geology; such methods had been used before their day—by William Smith in England, by Lehman in Germany, and by Desmarest in France. But these men, acting singly, had not been able to save geology from the eighteenth-century spirit of adventurous speculation, nor had they lifted from geology the burden of those quaint theories that made this science the butt of Voltaire's luminous ridicule.

The great achievement of the Geological Society has been this: As a corporate body it has been able to spread its influence very widely; its clear-sighted pursuit of a practical ideal has been adopted in other countries; its resolute rejection of the temptation to wander in dreamland has affected geological students all over the world. In this way has been laid a broad foundation of positive knowledge upon which modern geology has been built.

The fine self-restraint which induced the founders of the Geological Society to restrict its work for a while to observing the surface of the earth has had its reward. The methods this society was founded to employ have been so widely used that we now have geological maps of a wider area than was known to geographers of a century ago. The general distribution of all the rocks on the earth's surface has been discovered; most settled countries have been surveyed in some detail; the main outlines of the history of life on the earth have been written and carried back almost as far as paleontologists are likely to go. There are doubtless fossiliferous areas still undiscovered in the "back blocks" of the world; but, though negative predictions are proverbially reckless, it seems probable that paleontology will not carry geological history materially farther back. Fossils have been discovered in the pre-Cambrian rocks; the best known is the fauna described by Walcott from Montana; but his Beltina, the oldest well-characterized fossil, is still of Paleozoic type. It may be that the poverty of carbonate of lime, which is so characteristic a feature of most Cambrian and pre-Cambrian sediments, indicates that the bulk of the contemporary organisms had chitinous shells or were soft-bodied. Paleontology begins with the appearance of hard-bodied organisms; it can only reveal to us the dawn of skeletons, not the dawn of life. We are dependent for knowledge of the climate and geography of Eozoic time on the evidence of the sediments, of which there are great thicknesses beneath the fossiliferous rocks in most parts of the world.[a]

[a] Such are the Algonkian sediments represented by the Huronian and Algonkians of America, the Algonkians of Scandinavia, the Karelian of Finland, the Briovarian of Northwest France, the Heathcotian of Australia, the Transvaal and Swaziland systems of South Africa, the Dharwar and Bijawar systems of India, *the Itacolumnite series* of Brazil, etc.

THE GEOLOGY OF THE INNER EARTH.

Now that this geological survey of the earth is in rapid progress; while the history of life has been written at least in outline; the chief fossils, minerals, and rocks have been described and generously endowed with names; and the manifold activity of water and air in molding the surface is duly appreciated, it is not surprising to find that the center of geological interest is shifting to the deeper regions of the earth's crust and to the problems of applied geology. The secrets of these deeper regions are both of scientific and economic interest. They are of scientific importance, for it is now generally recognized that the main plan of the earth's geography and the essential characters of the successive geological systems are the result of internal movements. The relative importance of those restless external agents that we can watch, denuding here and depositing there, has been exaggerated; probably they do little more than soften the outlines due to the silent heavings produced by the colossal energies of the inner earth.

The study of the deeper layers of the crust is of economic interest, for, with keener competition between increasing populations and with the exhaustion of the most easily used resources of field and mine, there is growing need for the better utilization of soils and waters and for the pursuit of deeper deposits of ore.

If a shaft be sunk at any point on the earth's surface a formation of Archean schists and gneisses would probably always be reached; and, working backward, geological methods always fail at last—in primeval, Archean darkness. The Archean rocks still hide from us the earlier period of the earth's history, including that of all rocks which now lie beneath them. But already there are indications that the mystery of the "beyond" is not so impenetrable as it seemed.

1. *The nebular and meteoritic hypotheses.*—The eighteenth century explained the history of the earth by the nebular hypothesis of Laplace. Geologists respectfully adopted this idea from the astronomers; they accepted it as one of those essential facts of the universe with which geological philosophy must harmonize. The resulting theory represented the earth as originally a glowing cloud of incandescent gas, which slowly cooled, until an irregular crust of rock formed around a gaseous or molten core; as the surface grew cooler, the depressions in the crust were filled with water from the condensing vapor, forming oceans which became habitable as the temperature further fell. The whole earth was thought to have had a long period with a universal tropical climate, under which coral reefs grew where flow our polar seas, and palms flourished on what are now the Arctic shores. Still further cooling had established our climatic zones; and it was predicted that in time the polar cold would creep outward,

driving all living beings toward the equator, until at length the whole earth, like the moon, would become lifeless through cold, as it had once been uninhabitable through heat. This theory has permanently impressed itself on geological terminology; and its corollaries, secular refrigeration and the contortion of the shrinking crust, once dominated discussions concerning climatic history and the formation of mountain chains. This nebular hypothesis, however, we are now told, is mathematically improbable, or even impossible; and it is only consistent with the facts of geology on the assumption that, in proportion to the age of the world, the whole of geological time is so insignificant that the secular refrigeration during it is quite inappreciable; hence geology can no more confirm or correct the theory that a stock-breeder could refute evolution by failing to breed kangaroos into cows in a single lifetime.

The theory of the gaseous nebula has been probably of more hindrance than help to geologists; its successors, the meteoritic hypothesis of Lockyer and the planetismal theory of Chamberlin, are of far more practical use to us, and they give a history of the world consistent with the actual records of geology. According to Sir Norman Lockyer's meteoritic hypothesis, nebulæ comets and many so-called stars consist of swarms of meteorites which, though normally cold and dark, are heated by repeated collisions, and so become luminous. They may even be volatilized into glowing meteoric vapor; but in time this heat is dissipated, and the force of gravity condenses a meteoritic swarm into a single globe. Some of the swarms are, says Lockyer, "truly members of the solar system," and some of them travel around the sun in nearly circular orbits, like planets. They may be regarded as infinitesimal planets, and so Chamberlin calls them planetismals.

The planetismal theory is a development of the meteoritic theory, and presents it in an especially attractive guise. It regards meteorites as very sparsely distributed through space, and gravity as powerless to collect them into dense groups. So it assigns the parentage of the solar system to a spiral nebula composed of planetismals, and the planets as formed from knots in the nebula, where many planetismals had been concentrated near the intersections of their orbits. These groups of meteorites, already as solid as a swarm of bees, were then packed closer by the influence of gravity, and the contracting mass was heated by the pressure, even above the normal melting point of the material, which was kept rigid by the weight of the overlying layers.

This theory has the recommendation of being consistent with the history of the earth as interpreted by geology. For whereas the nebular hypothesis represents the earth as having been originally intensely hot, and having persistently cooled, yet geological records

show that an extensive low-level glaciation occurred in Cambrian times in low latitudes in South Australia;[a] indeed, it seems probable that, in spite of many great local variations, the average climate of the whole world has remained fairly constant throughout geological time. Whereas it has often been represented, in accordance with the nebular theory, that volcanic action has steadily waned, owing to the lowering of the earth's internal fires and the constant thickening of its crust, yet epochs of intense volcanic action have recurred throughout the world's history, separated by periods of comparative quiescence. Whereas it has been assumed, as a corollary to the nebular theory, that the force which uplifted mountain chains was the crumpling of the crust owing to the contraction of the internal mass, yet observation reveals that the crust has been corrugated, and fold mountains formed by contraction to an extent far greater than secular cooling can explain.

2. *The materials of the inner earth.*—This planetismal hypothesis is not only consistent with geological records, but also with the known facts as to the internal composition of the earth and the structure of extra-terrestrial bodies as revealed by meteorites. Meteorites are of two main kinds—the meteoric irons, which consist of nickel iron, and stony meteorites, which are composed of basic minerals. Some of the stony meteorites have been shattered into fault breccias, showing that they are fragments of larger bodies which were subject to internal movements, like those that have formed crush conglomerates in the crust of the earth. Those stony meteorites, therefore, both in composition and structure resemble the rocks in the comparatively shallow fracture zone of the earth's crust. The nickel-iron meteorites, on the other hand, represent the barysphere beneath the crust.

The earth appears to consist of material similar to that of the two types of meteorites; but whether the proportions of the two materials in the earth represent their proportions in other bodies and in meteoric swarms is problematical. There appear to be no satisfactory data for an estimate of the relative abundance in space of the iron and stony meteoric material. Stony meteorites have been seen to fall far more frequently than iron meteorites; but the largest known meteorites are of the nickel-iron group, although this material, in moist climates, very soon decays. The most reliable indication as to the relative amounts of the stony and nickel-iron meteorites is given by a comparison of the weight of the two types of material in meteorites of which the fall was seen. According to Mr. Fletcher's list of the meteorites in the British Museum up to 1904, the collection included 319 specimens of which the fall is recorded: of them 305 specimens were stony meteorites of an average weight of 2.63 pounds, 9 were iron

[a] As shown by the work of Professor Howchin, of Adelaide.

meteorites of an average weight of 2.31 pounds, and 5 were siderolites (or meteorites containing a large proportion of both silicates and nickel-iron) of an average weight of 54 pounds.[a] Therefore, according to this test the stony materials would appear to be the more abundant. But if all known meteorites are considered, the iron group far outweighs the other; for the iron meteorites in the British Museum collection weighed 11,873 pounds, as against a total weight of only 865 pounds of stony meteorites. The available evidence suggests that the stony meteorites fall the more frequently on the earth, but the meteoric irons come in such large masses that they outbalance the showers of the smaller stones.

We might have expected help from another source in examining what lies below the Archean rocks. Can not the relative proportions of the stony and metallic constituents in the earth help us? Unfortunately, this proportion is as uncertain as that of stony and iron meteoritic material. The best-established fact about the interior of the earth is that its materials are much heavier than those of its crust. The specific gravity of the earth as a whole is about 5.67; the specific gravity of the materials of the crust may be taken as about 2.5, while that of the heavier basic rocks is only about 3.0. Hence the earth as a whole weighs about twice as much as it would if it were built of materials having the same density as those which form the crust.

Two explanations of the greater internal weight of the earth have been given. According to one, the earth is composed throughout of the same material, and the internal mass is only heavier because it is compressed by the weight of the overlying crust. Laplace estimated that the material would gradually increase in density from the surface to the center, where its specific gravity would be 10.74, and the calculations of Schlichter show that condensation due to compression may be adequate to account for the greater internal weight.

According to the alternative or segregation theory, the difference in density is explained as due to a difference in composition; the interior of the earth is thought to be heavier owing to the concentration of metals within it. The probability of this metallic interior has been advanced from several lines of evidence; and the assumed metallic mass has received from Posepny the name of the "barysphere," or heavy sphere. According to this view the earth is essentially a huge ball of iron, which, like modern projectiles, is hardened with nickel; and it is covered by a stony crust, the materials of which were primarily separated from the metallic mass, like the slag formed on a ball of solidifying iron in a puddling furnace.

[a] The weights are given in pounds avoirdupois. For the calculation I am indebted to Mr. W. R. Wiseman, of the Geological Department of Glasgow University.

It has been objected that the weight of the earth is not great enough for much of it to be composed of metallic iron or of meteoritic material. The specific gravity of iron under the pressure at the earth's surface is about 7.7, and it would be even greater when compressed in the interior. But the barysphere is doubtless impregnated with much stony material that would lessen its weight. An estimate by Farrington (1897) of the average specific gravity of the meteorites of which the fall had been recorded is only 3.69. According to the Rev. E. Hill (1885), the mean specific gravity of all the meteorites in the British Museum was 4.5; and, though Mr. Hill duly considered the effect of compression, he concluded that "the density of the earth is perfectly consistent with its being an aggregation of meteoric materials." Moreover, within the metallic barysphere there may be a core of lighter material; for earthquake waves travel more slowly in the central core of the earth than in the intermediate zone, or are even suppressed altogether there; hence the center of the earth may be occupied by matter less compact than that of the shell around it; and, according to Oldham's calculations, the light central corps occupies two-fifths of the diameter of the earth.

The evidence of density alone, therefore, gives no convincing evidence of the nature of the earth's interior; and geologists have been left with no conclusive reason for choosing between the condensation and segregation theories. Radio-activity has, however, unexpectedly come to our aid, and has disclosed a further striking resemblance between the internal mass of the earth and the iron meteorites. It has supplied direct evidence about the constituents of the earth at depths which have hitherto been far beyond the range of observation. Mr. Strutt has shown that radium is probably limited within the earth to the depth of 45 miles, that the deeper-lying material is free from radium, and that this substance is not found in iron meteorites.

The agreement in radio-active properties between the iron meteorites and the interior of the earth is an additional and weighty argument in favor of the view that the earth is largely composed of nickel iron.

3. *Physical conditions and temperatures.*—The physical condition in which the material exists is now of secondary interest. The old controversy as to whether the earth has a molten interior inclosed within a solid shell has lost its importance, because it has become a mere matter of definition of terms. The facts which led geologists to believe that the interior of the earth is fluid are consistent with those which prove that the earth is more rigid than a globe of steel. For under the immense pressure within the earth the materials can transmit vibrations and resist compression like a solid; but they can change their shape as easily as a fluid. They are fluid just as lead is when it is forced to flow from a hydraulic press. Not only are geolo-

gists now justified in their belief that the deeper layers of the earth's crust are in a state of fluxion, but, according to Arrhenius (1900), the earth is solid only to the depth of 25 miles, below which is a liquid zone extending to the depth of 190 miles; and below that level, he tells us, "the temperature must, without doubt, exceed the critical temperature of all known substances, and at this depth the liquid magma passes gradually to a gaseous magma." This distinguished physicist gives a description of the earth's interior which reminds us of the views of the early geologists. Arrhenius's theory rests, however, on the existence within the earth of exalted temperatures; and this assumption a geologist may now hesitate to accept with less risk of getting into disgrace than he would have run a few years ago. It is improbable that the rapid increase of heat with depth which is observed near the surface should continue below the lithosphere; for, if the earth consists in the main of iron, even although it be arranged as a mesh containing silicates in the interspaces, the heat conductivity might be sufficient to keep the whole metallic sphere at a nearly equal temperature. Here, again, Mr. Strutt's work on radio-activity is in full agreement with the requirements of geologists, for he estimates that below a crust 45 miles thick the earth has a uniform temperature of only 1,500° C. Whether the further conclusion that this heat is due to the action of the radium in the crust be established or not, it is gratifying to hear a physicist arguing in favor of a moderate and uniform internal temperature.

All that the actual observations prove and that geological theories require is that the material within the earth be intensely hot, and that it lie under such overwhelming pressure that it would as readily change its form and as quickly fill up an accessible cavity as any liquid would do. Whether such a condition is to be described as solid, liquid, or gaseous is of little concern to geologists.

THE DEEP-SEATED CONTROL OVER THE EARTH'S SURFACE.

The modern view of the structure of the earth adds greatly to the interest of its study, for it recognizes the world as an individual entity of which both the geological structure and the history have to be considered as a whole. Once the earth was regarded as a mere lifeless, inert mass which has been spun by the force of gravity, that hurls it on its course into the shape of a simple oblate spheroid. Corresponding with this astronomical teaching as to the shape of the world was the geological doctrine that all its topography is the work of local geographical agents, whose control over the surface of the earth is as absolute as that of the sculptor's chisel over a block of marble.

Both these conceptions are now only of historic interest. The irregular individual shape of the earth is expressed by its description as a geoid. The processes which have produced its varying shape have also controlled its geological history and evolution, for they cause disturbances of the crust, which affect the whole earth simultaneously; and so the geographical agents are given similar work and powers at the same time in different places.

Hence there is a remarkable world-wide uniformity in the general characters of the sedimentary deposits of each of the geological systems. The last pre-Cambrian system includes thick masses of felspathic sandstones alike in the Torridonian of Scotland, the sparagmite of Scandinavia, the Keweenawan sandstones of the United States, and perhaps also the quartzites of the Rand. The Cambrian has its graywackes and coarse slates and its numerous phosphatic limestones, the Ordovician its prevalent shales and slates; the Silurian its episodal limestones and shales. The Devonian has its wide areas of Old Red sandstones as a continental type, while its marine representatives show the prevalence of coarse grits and sandstones in the lower series, of limestones and slates in the middle series, and the recurrence of sandstones in the upper series; and this sequence occurs alike in Northwestern Europe, in America, and Australia. The Carboniferous contains the first regional beds of thick limestone and the first important Coal Measures. The Trias is as characterized by rocks indicating arid continental conditions in America and Australia and South Africa, as Professor Watts has shown then prevailed in the neighborhood of Leicester. In the Mesozoic era we owe to Suess the demonstration of the world-wide influence of those marine encroachments or "transgressions" whereby the great continents of the Trias were gradually submerged by the rising sea.

Speaking generally, there is a remarkable lithological resemblance between contemporary formations in all parts of the world. This fact had been often remarked, but was usually dismissed as due to a number of local isolated coincidences of no special significance. But the coincidences are too numerous and too striking to be thus lightly dismissed. They are among the indications that the main earth changes have been due to world-wide causes, which led to the predominance of the same types of sedimentary rocks during the same period in many regions of the world.

The conditions that govern the geological evolution and general geography of the earth are probably due to the interaction between the earth's crust and the contracting interior; they may take place as slow changes in the form of the earth, causing the slow rising or lowering of the sea surface, or the slow uplift or depression of regions of the earth's crust; or they may give rise to periods of violent volcanic action in many parts of the earth, between which may be long

periods of quiescence. The geographical effects of changes in the earth's quivering mass affect distant regions at the same time. Therefore the landmarks of physical geology will probably be found to give more precise evidence as to geological synchronism than those of paleontology, on which we have hitherto had to rely.

PLUTONISTS AND ORE FORMATION.

Belief in the earth's internal fires was most faithfully held amongst geologists by the Plutonists of the eighteenth century and repudiated with equal thoroughness by the Neptunists, who refused to concede that volcanic action was due to deep-seated cosmic causes. Thus Jameson in 1807 stoutly maintained that volcanoes were superficial phenomena due to the combustion of beds of coal beneath fusible rocks, such as basalt, and that the explosions were due to the sudden expansion of sea water into steam by contact with the burning coal. Volcanoes, according to this view, were correctly described as burning mountains, giving forth fire, flame, and smoke. The extreme Neptunist and Plutonist schools have long since been extinct, but the controversy is not quite closed. The battlefield is now practically restricted to economic geology, and the issue is the origin of some important ores.

Ore deposits present so many perplexing features that deep-seated igneous agencies were naturally invoked to explain them, and some of the most thoroughgoing champions of the igneous origin of ores make claims that remind us of the eighteenth-century Plutonists. The question is to some extent a matter of terms. Many of the ores which Vogt, for example, describes as of igneous origin he attributes, not to the direct consolidation of material from a molten state, but to eruptive after actions due to the hot solutions and heated gases given off from cooling igneous rocks. Igneous rocks probably play a notable part in the genesis of most primary ore deposits; for the entrance of the hot ore-bearing solutions is rendered possible by the heat of the igneous intrusions, as Professor Kemp has well shown in his paper on "The Rôle of Igneous Rocks in the Formation of Metallic Veins." Professor Kemp limits the term "igneous" to materials formed by the direct consolidation of molten material; and this decision seems to me to be most convenient. For example, the quartzite that is so often found beneath a bed of basalt is due to hot alkaline water from the lava cementing the loose grains of sand; the process is an eruptive after action, but it would be unusual to call such a quartzite an igneous rock.

1. *Igneous ores.*—That there are ores which are the products of direct igneous origin is now almost universally admitted. The mineral magnetite is a most valuable source of iron, and it is a

constituent of most basic igneous rocks. If iron were a high-priced metal, such as tin or copper, of which ores containing 1 or 3 per cent are profitably worked, then basalt would be an ore of igneous origin. Under present commercial conditions, however, basalt can not be regarded as an iron ore. But if the magnetite in a basic rock had been segregated into clots or masses large enough and pure enough to pay for mining, then they would be iron ores formed by igneous action. There are cases of such segregations large enough to be mined. The most famous is Taberg, a mountain in Smaland, near the southern end of Lake Wetter, in Sweden. It is a locality of historic interest; a view of it, as a mountain of iron, was published by Peter Ascanius in the Philosophical Transactions[a] in 1755, and Sefström discovered the element vanadium in its ore in 1830.

Taberg consists of an intrusive mass of rock composed of magnetite, olivine, labradorite, and pyroxene. Many theories of its formation have been advanced. The view generally adopted is that of Törnebohm, who described the rock as a variety of hyperite in which there has been a central segregation of magnetite to such an extent that some of it contains 31 per cent of iron. Törnebohm claims to have traced a gradual passage from normal hyperite to a variety poor in feldspar, then to one without feldspar, and finally to a granular intergrowth of magnetite and olivine. This Taberg ore was mined and smelted for iron in the eighteenth century, when transport was more costly and commercial competition less keen than it is to-day. The ore has been worked at intervals as late as 1870; and as the hill is estimated to contain 100 million tons of ore above the level of the adjacent railway, it is not surprising that efforts are being again made to utilize the deposit, in spite of its low grade and high percentage of titanium. The Taberg hyperite has almost reached the line which divides magnetite-bearing rocks from useful iron ores. Its igneous origin, however, has not been universally accepted. The theory has been rejected by so eminent an authority as Posepny, according to whom the ore occurs in solid veins as well as in grains; and he holds that, like other Scandinavian iron ores, it was due to secondary deposition. During a visit to the mountain I failed to see any secondary veins, except of insignificant value. The microscopic sections of the ore show that it is a granular aggregate of olivine, generally with labradorite and pyroxene. Hence I have no hesitation in accepting the view of the Swedish geologists and regard Taberg as a magmatic segregation. Posepny[b] has in this case carried his Neptunist theory of the genesis of ores too far.

[a] Vol. XLIX, pp. 30–34, pl. II.

[b] F. Posepny, "The Genesis of Ore Deposits." Trans. Amer. Inst. Min. Eng., 1893, p. 323.

At Routivaara, in Swedish Lapland, there is a still larger mass of magnetite, which is claimed, in accordance with the descriptions of Petersson and Sjögren, to be due to segregation from the magma of the surrounding gabbro. This mass of magnetite is of colossal size, but it is of no present economic value owing to its high percentage of titanium and its remote position.

An igneous origin is claimed by Professor Högbom for some small masses of titaniferous magnetite in the island of Alnö, opposite Sundsvall, on the eastern coast of Sweden. This case is of interest, as the surrounding rock is not basic; it is a nepheline syenite, containing only 2 per cent of magnetite, which, however, has been concentrated in places, until some specimens (according to an analysis quoted by Professor Högbom) contain as much as 64 per cent of magnetite, 9 per cent of ferrous oxide, and 12 per cent of titanic oxide.

The Alnö magnetites, again, are of no practical value, as they are too low in grade and too refractory in nature. I understand that about 500 tons of the material have been smelted, but with unprofitable results, and the rest of the material quarried has been left on the shore. We may therefore accept the iron-bearing masses of Alnö and Routivaara, as well as that at Taberg, as due to magmatic segregation, without having conceded much as to the igneous formation of ores. The process in this case has formed rocks, rich in titaniferous magnetite, from which iron could be obtained, but rocks which no ironmaster is at present willing to buy as iron ore. Whether a basic igneous rock is to be regarded as an iron ore, or as only useful for road metal, depends on cost of treatment. The definition of the term "ore" is very elastic. Petrographers speak of the minute grains of magnetite or chromite in a rock as its ores; but that is a special use of the term "ore." Usually ore means a material which can be profitably worked as a source of metals under existing or practicable industrial conditions.[b] According to this definition, the Swedish deposits of titaniferous magnetite are at present doubtfully within the category of iron ores.

The famous iron mines of middle Sweden at Dannemorra, Norrberg, Grängesberg, and Persberg occur under different geological conditions; they work lenticles or bands of ores in metamorphic rocks, of which some are altered sediments; and the view has therefore been held by de Launay and Vogt that the ores also are altered sediments.

That ores are formed by igneous segregation of sufficient size and purity to be of economic importance is a theory which rests on two

[b] The Oxford Dictionary adopts a still more restricted definition; according to it an ore is "a native mineral containing a precious or useful metal in such quantity and in such chemical combination as to make its extraction profitable."

chief cases—the nickel ores of Sudbury in Canada and the iron ores of Swedish Lapland.

2. *The Sudbury nickel ores.*—The nickel ores of Sudbury are the most important historically. They have been repeatedly claimed as of direct igneous origin by Bell (1891), Von Foullon (1892), Vogt (1893), Barlow (1903), and by other geologists; and his view was advocated before the association at the Johannesburg meeting by Professor Coleman. The theory was stoutly opposed by Posepny in 1893, and Professor Beck in 1901 described some of the brecciated ore, and showed that its metallic minerals are sharply separated from the barren rock. He held that such ore must have been formed, not only after the consolidation of the rock, but even after or during its subsequent metamorphism. The views of Posepny and Beck seem to have been established by additional microscopic study of the ores by C. W. Dickson (1903). He has shown that the sulphides are separated from the barren rock by sharp boundaries, and without any indication of a passage between them; that the fragments of ore in the rock have short corners, whereas, had they grown in a molten magma, the angles would have been rounded and the faces corroded. Most of the ore, moreover, occurs as a cement filling interspaces between broken fragments of barren rock and along planes of shearing. The Sudbury ores, therefore, appear to have been deposited from solution during or after the brecciation of the rocks in which they occur, and long after their first consolidation. If Dickson's facts be right, the Sudbury ores are necessarily aqueous and not igneous in origin.

3. *Scandinavian iron ores.*—The other important mining field of which the ores are claimed as of igneous origin is Swedish Lapland. Its ores are rich and the ore bodies colossal. One mine, Kirunavaara, yielded over one and a half millon tons of ore in 1906, and according to a recent agreement with the Swedish Government the annual output of ore from that mine may be raised to three million tons by 1913.

The chief mining fields of Lapland, although situated to the north of the Arctic Circle, have long been known, for some of them contain veins of copper which were worked, for example, at Svappavaara in the seventeenth century. The iron ores, however, could not be used until a railway had been laid through the swamps of Lapland to carry the ores cheaply to the coast. In 1862 an ill-fated English company began a railway to the Gellivara mines, and thirty years later this was completed across Scandinavia, from the head of the Gulf of Bothnia at Lulea to an ice-free port at Narvik, on the Norwegian coast.

This railway, the most northern in the world, passes the two great mining fields of Gellivara and Kiruna. The mining field of Kiruna is the larger and at present of the greater geological interest, as its structure is simpler and its rocks less altered.

The ore body at Kiruna outcrops along the crest of a ridge 2 miles long, and it is continued beneath Lake Luossajarvi to the smaller but still immense ore body of Luossavaara. At Kiruna the ore rises to the height of 816 feet above the surface of the lake, and it varies in thickness from 30 to 500 feet, with an average thickness of about 230 feet. According to the report by Prof. Walfrid Petersson,[a] submitted this year to the Swedish Parliament, Kirunavaara contains 200 million tons of ore above lake level, and Luossavaara another 22½ million tons. The ore is high grade. According to Lundbohm 60 per cent of the trial pits showed a yield varying from 67 to 71 per cent of iron, and 21 per cent of them showed a yield of from 60 to 67 per cent of iron. The average of nineteen analyses published in Professor Petersson's recent report gives the contents of iron as 64.15 per cent. Unlike the Taberg and Routivaara ores, the percentage of titanium is very low; thus in nineteen analyses given by Petersson the average of titanic acid is only 0.23 per cent, and it varies in the specimens from 0.04 to 0.8 per cent.

The ore lies between two series of acid rocks, which have been very differently interpreted, but will no doubt be fully explained by the researches now in progress under the direction of Mr. Lundbohm. The rocks were first called halleflinta, as by Fredholm, and regarded as of sedimentary origin. They are now accepted as an igneous series, associated with some conglomerates, slates, and quartzites. The ore body itself is bounded on both sides by porphyrites, of which that on the lower or western side is more basic than that overlying the ore to the east. The basic western porphyrite is in contact with a soda-augite syenite of which the relations are still uncertain. Interbedded with the overlying eastern porphyrite are rocks that appear to be volcanic tuffs, and both in the tuffs and in the upper porphyrite are fragments of the Kiruna ore.

Three main theories of the genesis of the Kiruna ores have been proposed. Their sedimentary origin was urged on the ground that they occur regularly interstratified in a series of altered sediments, and that the ores, therefore, are also sedimentary. This view may be promptly dismissed, since the adjacent rocks are igneous.

The second theory has been advanced independently by Professor De Launay and Dr. Helge Bäckström. According to them the porphyrites above and below the iron ores are lava flows, and the ore was a superficial formation deposited in an interval between the volcanic eruptions. According to De Launay the iron was raised to the surface as emanations of iron chloride and iron sulphide; the iron was deposited as oxide, and most of it subsequently reduced to magnetite during the metamorphism of the district.

[a] Bihang till Rikd. Prot., 1907, 1 Saml., 1 Afd., 84 Häft, No. 107, pp. 213, 217.

The third theory—that the ores are of direct igneous origin—has been maintained by Löfstrand, Högbom, and Stutzer. According to them the ores are segregations of magnetite from the acid igneous rocks in which they occur. The segregation theory has been opposed, amongst others, by De Launay and Vogt. Thus, De Launay maintains that the segregation would have been impossible in such fluid lavas as the Kiruna porphyrites, and is improbable, since there is no transition between the ore and the barren rock.

The segregation theory has serious difficulties, and is faced by several obvious improbabilities. The ore occurs as a band nearly forty times as long as it is broad. It has the aspect, therefore, of a bed or a lode. The ore has not the granular, crystalline structure of an igneous rock like the hyperite of Taberg, but the aspect of a material deposited from solution or formed metasomatically. It is almost free from titanium, the undesirable constituent so abundant in the ores of Taberg and Routivaara.

The igneous theory can not, however, be lightly dismissed, as it is supported by the high authority of Professor Högbom, and therefore demands careful consideration.

It has been advanced in two main forms, the one considering the ore to have been deposited at the time when the igneous rocks were consolidating, the other considering it was deposited at a later period. According to Professor Högbom, the ore was syngenetic, being a true magmatic segregation from a syenite. But, according to Doctor Stutzer (1906), the segregation was later than the consolidation of the syenite. He describes the lode as an intrusive banded dyke, of which the chief constituents are magnetic and apatite; and the injection of this dyke pneumatolytically affected the rocks beside it, producing an intermediate zone impregnated with ore, which he compares to contact deposits.[a]

In spite of the high authority of Professor Högbom, I am bound to confess that the Kiruna ores do not impress me as of igneous formation. Their bed-like form, microscopic structure, and poverty in titanium are features in which they differ from those admittedly due to direct magmatic segregation. The microscopic sections that I have examined suggest that both the magnetite and apatite were deposited from solution and later than the consolidation of the underlying

[a] In a later paper, of which only a short abstract has been issued, Doctor Stutzer, however, explains that "the intrusion of the ore dyke was at relatively the same time as the formation of the syenite, and that the ores were formed by magmatic separations *in situ*, or as peregrinating magmatic separations (magmatic veins and bedded streams)." He adds that "pneumatolysis plays no inconsiderable rôle in the formation of these veins." Doctor Stutzer's position may be summarized as regarding the ores as collected by segregation, but deposited in their present position by eruptive after actions.

porphyrite, which the ore in part replaces. An examination of the field evidence supports the conclusions of De Launay and Bäckström as to the ore being a bedded deposit overlying a lava flow, but enlarged by secondary deposition.

FUTURE SUPPLY OF IRON ORES.

This conclusion is perhaps economically disappointing. The possible existence of such vast segregations of iron in the acid igneous rocks has an important economic bearing. There is only too good reason to fear that the chief iron ores are comparatively limited in depth; for most of them have been formed by water containing oxygen and carbonic acid in solution, which has percolated downward from the surface. Ores thus formed are therefore restricted to the comparatively limited depths to which water can carry down these gases. On the theory, however, that these ores are primary segregations from deep-seated igneous rocks there need be no limit to their depth. They would rather tend to increase in size downward, while maintaining, or even improving, in the richness of their metallic contents. For these bodies may be regarded as fragments of the metallic barysphere which have broken away from it and revolve around it like satellites floating in the rocky crust. On this conception these ore bodies would be of as great interest to the student of the earth's structure as their existence would be reassuring to the ironmaster, haunted as he is by constant predictions of an iron famine at no distant date. It is no doubt true that many of the richest, most accessible, most cheaply mined, and most easily smelted iron ores have been exhausted. The black-band ironstone and the clay iron ores of the coal fields, which gave the British iron industry its early supremacy, now yield but a small proportion of the ores smelted in our furnaces. The Mesozoic beds of the English Midlands and of Yorkshire still supply large quantities of ore. Nevertheless the British iron industry is becoming increasingly dependent on foreign ores. So it would be pleasant to find that the Scandinavian iron mines are not subject to the usual limits in depth. I fear the typical iron deposits of middle Sweden and of Gellivara will follow the general rule; but Kiruna may be an exception, and its ores may continue far downward along the surface of its sheet of porphyrite. The uncertainty in this case lies in the extent of the subsequent enrichment and enlargement of the bed; if most of the ore is due to secondary deposition, then it may be restricted to the comparatively shallow depths at which this process can act; and though that limit will be of no practical effect for a century or more to come, the ore deposit may be shallow as compared with gold mines.

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The geological evidence may convince us that all the economically important iron ores are limited to shallower depths than lodes of gold, copper, and tin; but this conclusion shall not enroll me among the pessimists as to the future of the iron supply. Twenty years ago a paper on the gold supplies of the world was read to the association at the request of the Section of Economics. About the time that the report was issued there were sixty-eight mining companies with a nominal capital of £73,000,000 at work upon the Rand. Nevertheless, the author, accepting the view that "the future of South African gold mining depends upon quartz veins," concluded: "There is as yet no evidence that the yield will be sufficient in amount to materially influence the world's production. As regards India, the prospect is still less hopeful."

That quotation may be excused, as it is not only a warning of the danger of negative predictions, but of the unfortunate consequences that happen when geologists are unduly influenced in geological questions by the opinions of those who are not geologists. In economic geology, as in theoretical geology, we should have greater confidence in the value of geological evidence. Negative predictions are especially rash in regard to iron, it being the most abundant and widely distributed of all the metals. The geologist who knows the amount of iron in most basic rocks finds it difficult to realize the possibility of an iron famine; he can hardly picture to himself some future ironmaster complaining of "iron, iron everywhere, and not a ton to smelt." There are reserves of low-grade and refractory materials which the fastidious ironmaster can not now use, since competition restricts him to ores of exceptional richness and purity. When the latter fail, an unlimited quantity could be made available by concentration processes. The vast quantities of iron ores suitable for present methods of smelting in Australia, Africa, and India show that the practical question is that of supplies to existing iron-working localities, and not of the universal failure of iron ores.

MINING GEOLOGY AND EDUCATION.

The genesis of ores and the extent of future ore supplies are intimately connected questions, and the recognition of this fact has led to the remarkable growth of interest in economic geology. This wider appreciation of the practical value of academic geology should, I venture to urge, be recognized among teachers by giving a more honored place to economic geology.

It was inevitable that until the principles of geology had been firmly established, the detailed study of their application should have been postponed. Now, however, last century's work on academic geology enables the difficult problems connected with the genesis of

metalliferous ores to be investigated with illuminating and practically useful results.

British interest in mining education has therefore been revived. Its history has been sadly fitful. Lyell,[a] in 1832, deplored the superiority of the Continent in this respect, as "the art of mining has long been taught in France, Germany, and Hungary in scientific institutions established for that purpose," whereas, he continues (quoting from the prospectus of a school of mines in Cornwall, issued in 1825), "our miners have been left to themselves, almost without the assistance of scientific works in the English language, and without any 'school of mines,' to blunder their own way into a certain degree of practical skill. The inconvenience of this want of system in a country where so much capital is expended, and often wasted, in mining adventures, has been well exposed by an eminent practical miner."

Though the chief British school of mines made a late start, the brilliant originality of its professors soon carried it into the front rank; but in an evil day for the mining school it was united with a normal school for the training of teachers, now the Royal College of Science, and that school by its great success overwhelmed its older ally. Those interested in economic geology therefore welcome the recent decision to separate the technical from the educational and other courses, while leaving the schools of mines and science sufficiently connected for successful cooperation. This policy should give such opportunities for the teaching of mining research that we may not always have to confess, as at present, that British contributions to mining geology do not rank as high as those made to other branches of our science.

Regrets are sometimes expressed, and perhaps still more often felt, at the tendency in scientific teaching to become more technical; but I, for one, do not fear evil from any such change. It is possible that the educational conflict of the future will be between academic science and technical science, on grounds in some respects analogous to those between classics and science during the last century. The advocates of the educational value of technical science are not inspired by mere impatience with the apparently useless, for they accept the principle that the essence of education is method, not matter. Therefore, they claim that the methods and principles of science can be better taught by subjects which are being used on a large scale in modern industries than by subjects of which the interest is still purely theoretical. Those who fear that academic science will be neglected if technical science be used in education may be encouraged by the brilliant revival of classical research since classics lost its educational monopoly. Academic science is even less likely to be neglected. It will always

[a] C. Lyell, "Principles of Geology," Vol. I, 2d ed. (1832), p. 63.

have its fascination for those intellectual hermits—shall I not say those saints of science?—who prefer to work for love of knowledge, free from the worrying intrusion of the mixed problems and fickle conditions of the industrial world; and the greater the progress of applied science the more urgent will be its demands for help from pure science, and, as a necessary consequence, the wider will be the appreciation and the more generous the endowment of scientific research.

Technical education must be as rigorous as that in academic education, and its connection with the fundamental principles must be as intimate. When so taught, economic problems provide at least as good a mental training as those branches of science which are purely theoretical. If the new Imperial College of Science and Technology carry on the mission for which the Geological Society was founded a century ago, if it inspire its students to have their delight in using past discoveries on the open surface of the earth, so that they may penetrate to what is within, then they will gain that sure knowledge of the formation and distribution of ores which is of ever-growing national importance.

THE SALTON SEA.

By F. H. NEWELL,
Director U. S. Reclamation Service.

GENERAL STATEMENT.

The Salton Sea and its apparently miraculous growth has given
s to almost innumerable popular articles and discussions, many
which are founded upon misapprehension of the facts. The
lacies of statement and of conclusion, both as to the origin
the Salton Sea and as to its beneficial effect upon the gen-
l climate of southwestern United States, are both interesting and
using. The phenomena connected with its rapid increase in size
re attracted wide attention and most astonishing tales have been
d of the sea and of its benefits to surrounding areas. At the same
ie a full knowledge of the changes which have been and are taking
ce is highly instructive.

As a matter of fact the sea is not a sea at all, as shown in
I, but an accumulation of waste water in the bottom of a depres-
n below sea level. Relatively to a real sea it is a mere puddle or
uck pond" in a vast extent of arid desert, which at one time was
s floor for a large body of fresh water. It is not a new thing but a
rival in historic times of what has probably occurred frequently
geologic history. The widely advertised effect upon the climate
the expanded Salton Sea is practically negligible. The wonderful
sults attributed to the sea in increasing the rainfall in the South-
stern States and Territories is a case of "placing the cart before
s horse," that is to say, the apparent increase in rainfall throughout
s West is more likely to have been an indirect cause of the increase
area of the Salton Sea than the reverse.

LOCATION.

The so-called Salton Sea or Cahuilla Lake of Dr. W. P. Blake
a body of highly saline water in what has been until recently
n Diego County, now Imperial County, California. This county
adjacent to the Mexican border lying immediately west of the

Colorado River. A great, if not the greater, part of the county is below sea level, and the Salton Sea consists of the waste or seepage water which has found its way to the lowest point in the broad extent of depressed desert lands.

In former geologic times the head of the Gulf of California extended about 150 miles farther north than it does at present. Through causes to be later described the head of the gulf was cut off, leaving a depression filled with water but disconnected from the gulf by a broad area of low land. This water gradually diminished through evaporation until when the country was first discovered by the white man there was little if any of the water left in the deepest part of the basin, about 300 feet below sea level. This small remnant of water by reason of concentration by evaporation is extremely salt, so much so that a salt factory was established in its margin.

Its original outline when discovered by white men is not accurately known, as the shores have such a gentle slope that with the covering of salt upon the margin it was difficult from a distance to determine where the water ended and the comparatively dry land began. It is possible that in some years the water may have entirely disappeared, leaving broad flat plains of white salt resembling in the distance the waves of an inland lake.

PECULIAR GEOGRAPHY.

The peculiar geographic conditions are determined largely by the fact that the Colorado River of the west, draining a considerable portion of the arid regions of the United States, flowed not directly into the ancient head of the gulf but entered this body of water at a point about 100 miles below the head. The extremely muddy river, carrying the washings from the mountains and plateaus of the north, deposited its load of sediment on reaching the salt water and spread this out in a broad alluvial fan, ultimately filling that portion of the gulf, cutting off the head and leaving it as a detached body of water.

The Colorado River, flowing out upon the broad delta of mud, wandered in many channels at different times, occasionally turning northward into the cut-off portion of the gulf and again turning southward into what is now the head of the present Gulf of California. There are thus left innumerable ancient channels, some of them intersecting and all of them with very low banks over which the water pours in broad sheets in time of flood.

The channel of the Colorado River, as known in historical times, and its proper channel as far as political divisions are concerned has a nearly southerly course, extending from about the location of *the town of* Yuma to a point near the head of the Gulf of California.

But this channel is by no means fixed by nature. The river reserves the right in time of flood to wander where it pleases and to spill over its banks. During the process of spilling it builds up its banks and tends to raise the entire country by the deposit of the mud. As the flood recedes the waters generally return to the former channels and close, by deposits of mud, the outlets which have been made during the flood season.

UNSTABLE CONDITIONS OF THE COLORADO RIVER.

The river may be considered to be in unstable equilibrium. There is to the west and northwest a large extent of land which is lower than the bed of the river, and when the stream occasionally gets out of its normal channel and finds one or more of its old channels running off toward the north or northwest, its waters ultimately converge toward the depression in which is now located the body of water we know as the Salton Sea. Thus, although nature has arranged that the river shall return usually to the channel it has been occupying for many hundreds of years, yet occasionally it is permitted to wander at will and to discharge some of its surplus waters northerly into the ancient lake bed.

With these conditions of unstable equilibrium, as above noted, it requires only a very little interference from man to induce the river to leave its ancient channel and to wander away into some of the courses pursued in its youth. This interference has taken place, and as a result we have the rapid increase in accumulation of waste waters in the sink or depression, this increase being particularly noticeable during the years 1906 and 1907.

CONTINUAL DANGERS OF OVERFLOW.

If man will keep out of this ancient basin in which the waters of the Colorado River have gathered from time to time, little may be written. If we go into this depression below sea level and interfere with natural conditions, or, as we say, "develop the country," we are brought face to face with the great forces of the river and the uncertainty as to whether it will desire to continue in the channel in which we happened to have found it. The river may take a notion at any time to resume some one of its former channels and to fill with water the basin lying below sea level, and which has always been subject to its play. It holds over the settler and tiller of the soil, or town builder, the threat that, unless continually watched or checked, it may prefer to flow not southerly into the Gulf of California but to turn abruptly to the north and swell the waters of the Salton Sea.

These old channels, some of them intertwining and scarcely distinguishable upon the surface, have not all been traced out, but a few of them are so well marked as to have received a distinct name and are shown upon the map. The most northerly of these, the one lying immediately south of the international boundary, is known as the Alamo. South of this the next decided channel or series of channels is called the Padrones, and still south of these is a channel known as the Pescadero, this latter extending westerly to an open body of water known as Volcano Lake, from the fact that it is surrounded by a number of very remarkable small mud volcanoes.

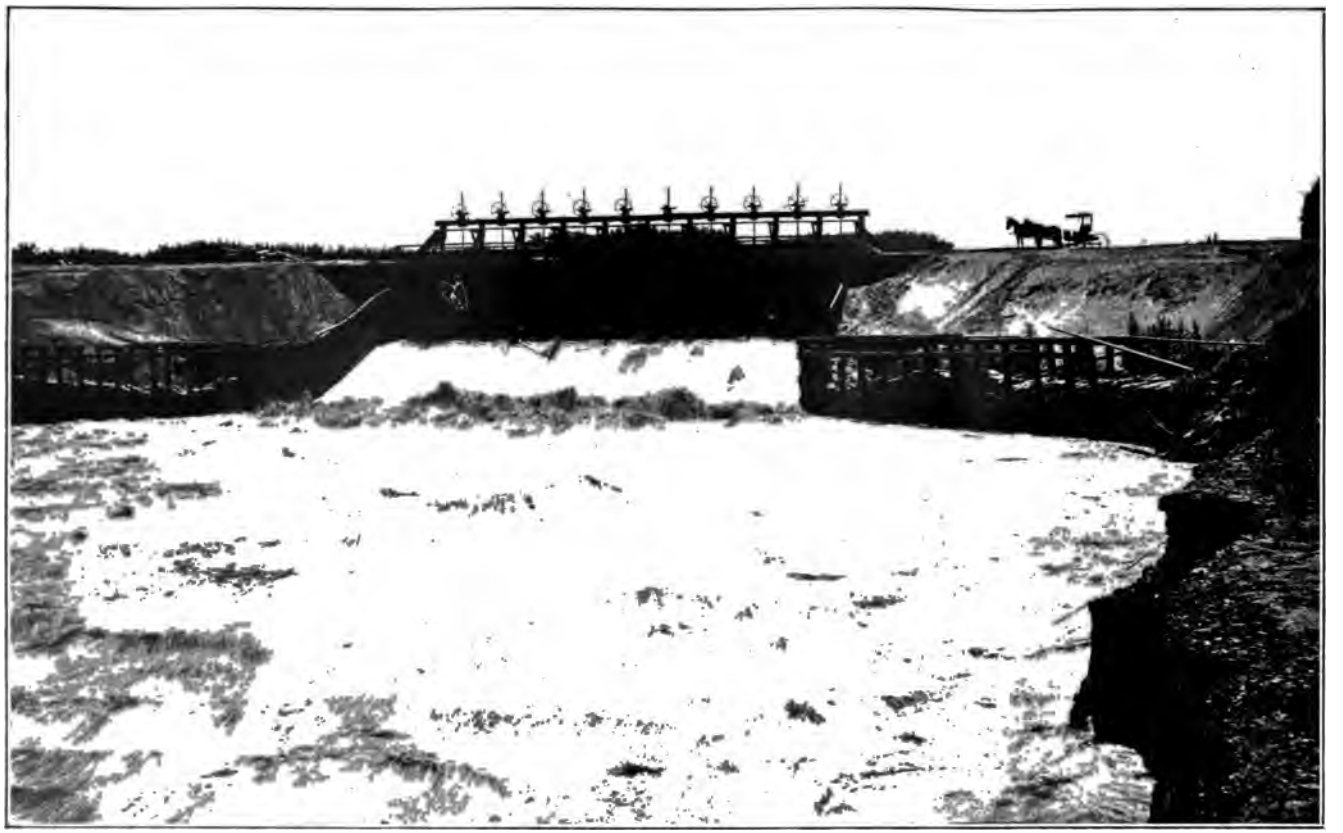
Extending northerly from Volcano Lake are channels, leading through New River, paralleling in places the Alamo and ending in the Salton Sea. Leading southerly from Volcano Lake and from the channels of the Pescadero is a broad stream known as Hardy's Colorado, one of the largest of the ancient beds of the great river, which joins the latter shortly before it enters the Gulf of California.

HISTORY OF RECENT OVERFLOW.

To understand the cause of the recent rapid increase in the Salton Sea it is necessary to go back a little into the history of the development of the desert land lying south of the Salton Sea. This land has been known for some decades and has had a reputation of extreme aridity. Certain adventurous men, more far-sighted than others, however, saw the possibilities of agricultural development, and after much negotiation finally formed a company which, through a subsidiary corporation formed under the Mexican law, succeeded in perfecting plans for diverting some of the water of the Colorado River. This was done by a cut in the west bank of the river in the United States near the international boundary. The ditch or canal thus made carried water south across the line into Mexico, and then into the head of one of the ancient channels of the Alamo River. This company is known as the California Development Company of New Jersey. Its subsidiary Mexican corporation is known as La Sociedad de Yrrigacion y Terranos de la Baja California (Sociedad Anonima).

Finally the water is diverted back into the United States and is there disposed of to numerous corporations of irrigators for the purpose of receiving and distributing the water to the cultivators of the soil. Pl. II shows the timber head gates at what is known as Sharp's heading, upon which depends the water supply of the lands of Imperial Valley.

The project of reclamation of the desert was an ambitious one and with the capital available was, to say the least, hazardous. In fact, it is doubtful whether the original promoters of the enterprise realized the great expenditure which would be necessary to make this a



HEADWORKS OF THE IRRIGATING SYSTEM IN THE IMPERIAL VALLEY AT SHARP'S HEADING IN MEXICO.

permanent success. However, there is much to be commended in the vigor and energy with which the difficulties were met and the obstacles overcome for the time being. Water was actually led from the Colorado River around the sand hills which lie along the international boundary and then distributed to the canals of the irrigators covering the desert land below sea level and stretching northerly from the Mexican boundary nearly to the Salton Sea.

The very boldness of the undertaking and the novelty of the situation added to the popular interest, which was stimulated by advertising. Thousands of settlers came in and took up the land under the homestead or desert land acts; the water was applied to the fields and thousands of acres were brought under irrigation. The success attained was from the first notable and the failures were overlooked in the general prosperity resulting from the rapid increase in population.

THE CUT IN THE BANK OF THE RIVER.

Under the original plans water was to be taken out into the United States, conducted in a canal nearly parallel to the course of the river, but slightly diverging from it, until the canal reached one of the many natural sloughs or depressions which led into the Alamo channel. A second heading was made immediately below the international boundary, so that water could be taken into the canal either in United States soil or in Mexico. The rapid development of the country and increasing demand for water and the difficulties of keeping open the original heading, due to the accumulation of sediment, finally forced the owners of the canal to look about for some quicker way of getting the needed supply to the agricultural lands.

About the time that the greatest need of water was felt in the valley the California Development Company appears to have reached its limits as regards funds, and with the pressure from the farmers for more water, it became necessary to make a hazardous move. It was finally determined, much against the advice of the engineers, to cut into the bank of the river and make what is known as heading No. 3, about 4 miles below headings No. 1 and No. 2. This latter heading afforded a short, quick descent from the river to the Alamo channel.

Accordingly, in October, 1904, what is known as heading No. 3, this being 40 to 50 feet wide and 6 to 8 feet deep, was cut in the mud bank of the river and a small amount of water was allowed to flow down, relieving the needs of the farmers. The California Development Company did not have approved plans or funds available to build head works in this opening, and it was assumed that, with ordinary care and watching, the channel could be kept open just sufficient to allow the needed amount of water to pass out from the *west bank.*

With the next rise in the river, however, the fears of the engineers were fulfilled. Following a capricious mood, the river concluded to go down the easy channel toward the Alamo and sent from day to day an ever-increasing flood, rapidly eroding the channel. This continued until, in the spring of 1905, the entire river was passing by an abrupt turn to the westward down the Alamo channel, spreading out over the low ground, and ultimately converging toward Volcano Lake, or northerly into the New River and the Salton Sea.

The old channel of the river, where it formed a part of the international boundary and at points below, soon became completely dry and rapidly assumed the ordinary appearance of the alluvial desert. Willows quickly sprung up, and in the course of a few years, under the influence of the winds and rapidly growing vegetation, the channel would have disappeared as a conspicuous feature.

CUTTING OF NEW CHANNEL.

The water entering through heading No. 3 filled to overflowing the natural bed of the Alamo. It swept out across the desert, diverging and converging, forming many streams, and in places covering the nearly level ground with a sheet of water which extended as far as the eye could reach. All of the soil of this country had been deposited by the wind or by the river in its previous excursions, and hence consisted of extremely soft layers of sandy silt or fine mud. As the water progressed toward the depression filled by the Salton Sea it tended to gather into narrow streams. Gaining velocity with increase of slope, these began quickly to establish for themselves definite beds by scouring out the soft material. At first slight falls or riffles were formed. Later these progressed backward, deepening as the water scoured out the channel which had formed in the soft earth.

Converging from broad sheets, water poured over the edges of the rapidly eroding silt and in some places, as shown in Pl. IV, formed waterfalls comparable almost to Niagara in their size and in their apparent height, when compared with the broad level plain. These falls in some places in the softer beds progressed backward at the rate of about a mile in three days. Occasionally the water would strike a harder layer and the rate of progress would be slower. As these falls retreated backward, forming a definite channel for the waters, the broad expanse was suddenly drawn down, and what was to the eye a wide lake became in a few hours a mud flat, traversed by a deep, narrow gorge, a thousand feet or less in width, filled by a foaming torrent.

Sometimes the water coming from Colorado River overflowed the fields of the farmers and the grain or alfalfa was overtopped by the

AGRICULTURAL LAND DESTROYED BY FLOOD WATER.

WATER FROM COLORADO RIVER CONVERGING INTO DEFINITE CHANNEL, CUTTING ITS FALLS RAPIDLY UPSTREAM.

LOOKING SOUTHERLY OVER TEMPORARY DIKES IN THE SUBMERGED TOWNS OF CALEXICO AND MEXICALA.

muddy flood. The waters converging to form the channel as above described would dig through the fields these narrow, deep gorges, as shown in Pl. III, and forever destroy what had been a prosperous home. In a few cases, where small towns had been built, such as Calexico and Mexicala, the inhabitants gathered together and with strenuous exertions, working day and night, attempted by means of low dikes to hold back the flood and direct its course. A view looking over one of the dikes is given in Pl. IV. In the case of Mexicala the converging torrents, forming a deep channel, began to progress in their cutting toward the town. Attempts were made by means of heavy explosives to change the direction of the back cutting and turn it away from the settled country. All this, however, was without effect, and the wide, deep channel turned abruptly toward the town, cutting a chasm, as shown by Pl. V, into which toppled, in succession. houses and barns, the railroad station and a large part of the railroad track.

It soon became apparent that the danger of this back cutting was not confined alone to the destruction of agricultural lands and of houses and fields; but that if it continued it would ultimately involve the heads of the canals leading water out to the remaining agricultural lands. When once the heads of these canals were cut off by the retreat of the channel it would be impossible to keep an adequate supply for the valley. In other words, once these headings were destroyed, although there would be a flood rushing down to Salton Sea through deep, steep-sided walls of earth, as shown in Pl. VI, yet there would not be any water available on the surface for the crops or for the ordinary uses and necessities of man and beast. More than this, it was readily appreciated that the back cutting, continuing to the Colorado River, would in time lower the bed of that stream, and allow it to deepen at Yuma to a point where it would no longer be possible to divert water by gravity for irrigation in the vicinity of that town. Then continuing upstream, it would imperil the safety of the great dam being built by the Government across the Colorado River. The situation became very serious and alarm was felt for the future, not merely of the lands under cultivation in Imperial Valley, but of those along the Colorado River in California and Arizona.

RISE OF THE SALTON SEA.

The rapid influx of the entire volume of the Colorado River was quickly noticeable in the steady rise of the Salton Sea, which, swollen by the muddy torrent, gradually engulfed the works of the New Liverpool Salt Company and creeping up on the ranches near Mecca, threatened to submerge the main line of the Southern Pacific Railroad.

The bottom of the sink in November, 1904, just after the cut was made, stood 273.5 feet below mean sea level. The rise during November and December of that year was 0.8 feet. During 1905 it was 21.9 feet. In 1906 the water continued to rise and increased in depth by 49.8 feet; but in 1907 the closing of the break in February was followed by a decline, beginning in March, the net fall being, however, only 0.18 feet. The level on January 1, 1908, was 201.18 feet below mean tide.

The following table gives the amount of rise and fall by months, together with the altitude of the water surface at the end of each year, the principal data being obtained from the report of W. B. Clapp, printed on page 33 of Water Supply and Irrigation Paper No. 213 of the U. S. Geological Survey:

Rise and fall of the Salton Sea, in feet.

Month.	1904.	1905.	1906.	1907.	1908.
January	----------	1.4	1.1	2.85	—0.02
February	----------	1.6	1.8	0.70	—0.10
March	----------	0.8	2.7	—0.10	—0.22
April	----------	1.2	5.6	—0.30	—0.38
May	----------	1.0	8.6	—0.55	—0.55
June	----------	2.2	15.4	—0.40	----------
July	----------	4.4	8.6	—0.15	----------
August	----------	2.2	2.9	—0.30	----------
September	----------	1.2	0.9	—0.70	----------
October	----------	1.4	1.2	—0.40	----------
November	0.6	1.6	—0.2	—0.55	----------
December	0.2	2.9	1.2	—0.28	----------
Net rise	0.8	21.9	49.8	—0.18	----------
Altitude at end of year	—272.70	—250.80	—201.00	—201.18	----------

The area of the Salton Sea at various elevations is shown in the following table prepared by W. B. Clapp, of the U. S. Geological Survey:

Area of the Salton Sea.

Distance below sea level, in feet.	Area, in square miles.	Difference, in square miles.	Distance below sea level, in feet.	Area, in square miles.	Difference, in square miles.
270	246	26	170	587	45
260	272	27	160	632	48
250	299	29	150	680	50
240	328	30	140	730	52
230	358	33	130	782	54
220	391	37	120	836	56
210	428	38	110	892	60
200	466	39	100	952	300
190	505	40	50	1,252	586
180	545	42	0	1,788	----------

ONE OF THE CHANNELS PASSING THROUGH THE TOWN OF MEXICALA

CHANNEL CUT BY THE NEW RIVER ON ITS WAY TO SALTON SEA.

In its course from New Orleans to Los Angeles the Southern Pacific system, passing through southern Arizona, reaches the Colorado River at Yuma, which it crosses on a bridge leading north. It then swings westwards and, climbing over a low ridge, descends into the depression occupied in part by the Salton Sea. When it reaches a point about 250 feet below sea level, it begins to climb out northwesterly through the passes which lead to the valleys in which are situated the prosperous towns of southern California.

The Salton Sea had only a few feet to rise before it seriously interfered with traffic on the Southern Pacific. The wind driving the waters toward the railroad imperiled the track, and it became necessary to rebuild it rapidly at a higher elevation. This was done several times in succession, and temporary track after temporary track was laid down out of immediate reach of the waters in the hope that the floods would subside. Popular attention was drawn to this increase in water in the sea, and without seeking the cause many statements were printed to the effect that the ocean had broken through a crack or fissure in the earth and was coming up through the bottom of Salton Sea. The very simple explanation of the flow of the Colorado River into the lake was not accepted by the seekers for the miraculous and many profound theories were promulgated, defying the laws of geology or of nature in general.

The Southern Pacific officials, however, were well aware of the cause of the difficulty under which they were laboring, and finally, finding that the California Development Company were unable to control the floods, they, by an agreement dated June 20, 1905, virtually took possession of the company, loaning it sufficient money to begin the attempt to close the break. They also rebuilt 40 miles of track on the 200-foot contour below sea level and for possible future use graded another line on the 150-foot contour below sea level.

CLOSING THE BREAK IN THE COLORADO RIVER.

The history of the attempts to close the break are exceedingly interesting from an engineering standpoint and the successive failures are highly instructive to one concerned with the control of alluvial streams. An excellent description is given by Mr. C. E. Grunsky in the Transactions of the American Society of Civil Engineers for December, 1907.

In all, seven or eight distinct attempts were made with almost as many failures. In each case success was nearly attained, but through some inadequate preparation or sudden rise of the river the works were swept away. It seemed as though the river were taking a malicious delight in thwarting the efforts of the engineers. At first it was assumed that the expenditure of a small amount of money would

be sufficient to close the break. The throwing back of the river into its original channel was looked upon as merely an ordinary effort in engineering work. When, however, attempt after attempt failed and larger and larger expenditures were made until over a million dollars were involved, the Southern Pacific officials began to awake to the fact that they had a difficult problem on hand and one which required far better equipment and preparation than had been before provided. Finally the supreme effort was made, and on November 6, 1906, the break was closed and the river forced to resume its normal channel to the gulf.

This condition continued for just about a month when, on December 7, 1906, the river in a sudden rise forced its way under the dikes, in a few hours swept away a portion of the protecting works, passed around the rock dam, and again found its way to the Salton Sea. Then came popular despair. A million dollars had been expended and there seemed no way of putting the river back again in place without having available an equipment and a sum of money beyond the reach of the people most immediately interested. Appeals were made to the governor of California and by the governor of California to the President of the United States. These were given prompt attention. President Roosevelt took the matter up at once and hastened to investigate, finding that the only man who could handle the situation, who had the equipment, the money, and the facilities was Mr. E. H. Harriman, the president of the Southern Pacific Company, who at the same time controlled the destinies of the California Development Company.

At first, in the pressure of large affairs, Mr. Harriman overlooked the fact that he was virtually the controller of the destiny of the California Development Company, and through this of the fortunes of a large community. He hesitated to advance more money and wired to the President to this effect. Mr. Roosevelt, in his telegram of December 20 to Mr. Harriman, stated that—

> This is a matter of such vital importance that I wish to repeat that there is not the slightest excuse for the Development Company waiting an hour for the action of the Government. It is its duty to meet the present danger immediately and then the Government will take up with it, as it has already taken up with Mexico, the question of providing in permanent shape against the recurrence of the danger.

Mr. Harriman's reply on the same day stated that—

> You seem to be under the impression that the California Development Company is a Southern Pacific enterprise. This is erroneous. It has nothing to do with this work or the opening of the canal. We are not interested in its stock and in no way control it. We have loaned it some money to assist its dealing with the situation. What the Southern Pacific Company has done was for the protection of settlers as well as of its tracks, but we have determined to move the tracks to higher ground anyway. However, in view of your message, I am

giving authority to the Southern Pacific offices in the West to proceed at once with efforts to close the break, trusting that the Government as soon as you can secure the necessary Congressional action will assist us with the burden

The President, in reply, said:

I am delighted to receive your telegram. Have at once directed the Reclamation Service to get into touch with you so that as soon as Congress reassembles I can recommend legislation which will provide against a repetition of this disaster and make provision for an equitable distribution of the burden.

As a result of these telegrams, received in rapid succession, Mr. Harriman concluded again to make an effort, and on January 12, 1907, the President, in accordance with his promise, laid the whole matter before Congress. The final effort was successful and before the time of the spring flood of 1907 the river had once more been restored to its proper channel. During the summer a series of dikes were built, intended to prevent any possibility of a recurrence of the danger in that part of the river.

DIFFICULTY OF CLOSURE.

To one who is accustomed to the surroundings of the ordinary river, the problem of turning back the Colorado River into its former channel may not appear to be a very difficult matter. But, to explain the reason of the failures in rapid succession, it should be borne in mind that the river at this point flows over deposits of silt and fine sand whose character is such that under a swift current they are torn up and carried away with wonderful rapidity. Whenever the channel in any notable degree was confined, the water at once began burrowing and cutting so that in some cases it is claimed that wooden piles over 70 feet long were cut out by the river faster than they could be driven.

It was a simple matter to bring the work of closure or diversion to a point where it seemed as though the river could be quickly turned, but the constriction of the channel due to any structure resulted in increasing the speed of the water and in adding to its consequent erosive force to an extent such that in a few hours enormous gaps were created.

Added to the unfavorable character of the bed and banks was the fact that the river seldom remained quiet for any considerable length of time. It was subject to short violent floods, especially from its tributary, the Gila. These occurring at a time when the work was in a critical condition quickly rendered useless the efforts of the constructors.

The method finally adopted for turning the stream was one whose success depended upon having at hand a large railroad equipment and an enormous amount of material which could be quickly transported.

The closure completed in December, 1906, and the closure made the following spring were essentially similar in plan. Piles were driven across the break, as shown on Pl. VII, and upon these parallel lines of railroad were constructed. Two and in some cases three parallel tracks were thus provided, so that trains could be rapidly operated and run out over the break, crossing it and having ample switching facilities on the far side.

When all was in readiness train load after train load of large stones were run out over the gap and dumped as rapidly as possible, the effort being to put in rock faster than the river could wash it away. A large amount of material was washed down the stream for a hundred and fifty feet or more and the bottom of the channel in which the large stone sank was rapidly cut. By carefully watching, however, and sounding so that the holes as they formed could be detected and filled, it was found possible to build up a broad low heap of large stone immediately under the railroad trestle.

The chief difficulty was to secure a sufficient supply of stone fast enough to fill the gaps as washed out. In some cases it is stated that trains of flat cars loaded with stone were brought from a distance of 400 miles. They came from quarries located not only on the Southern Pacific but also on the Santa Fe and San Pedro railroads. In fact, it is stated that even high-grade cut stone en route for building was requisitioned and diverted to fill the need.

The stones used were as large as could be handled or pushed from the flat cars by a gang of men or by as many men as could get around a stone. In some cases the pieces were so large that it was necessary to break them by what are called " pop-shots " of dynamite laid upon the stone while it rested on the cars. In this way the stones were broken and then could be readily thrown overboard by hand.

The scene at the closure of the break was exciting; train after train with heavy locomotives came to the place and the stones large and small were pushed off by hundreds of workmen as rapidly as the cars could be placed. While waiting to get out upon the trestle the larger stones were broken by the " pop-shots." The noise sounded like artillery in action. Added to the roar of the waters were the whistle signals, the orders to the men, and the bustle of an army working day and night to keep ahead of the rapid cutting of the stream.

As the rock heap rose gradually, it checked the river, causing it also to rise higher and higher and to cascade over the pile of stone. Riffles were caused and an undercutting of the lower slope or of the rock heap allowed it to settle and the stones to roll downstream. All of this undercutting and settling had to be made up and overcome by the rapid dumping of other large stones.

It was necessary to raise the river bodily about 11 feet. As the water rose and became ponded on the upper side of the rock heap,

THE BREAK IN THE WEST BANK OF THE COLORADO RIVER, AUGUST 26, 1906.

THE BREAK IN THE WEST BANK OF THE COLORADO RIVER, NOVEMBER 13, 1906.

train load after train load of small stone and gravel from the nearby hills were dumped to fill the spaces between the large rocks.

Finally, after days and nights of struggle, the water was raised to a point where it began to flow down its former channel and less and less to pass over the top of the rock heap. Then finer material was added and rapidly piled up on the accumulated rock mass. The lower side of this loose rock dam is shown in Pl. VIII. On the far side beyond the rock dam and the railroad trestle is the river, as indicated by the steamboat lying alongside of the track.

At first a large amount of water passed through the rock heap and steps were taken as rapidly as possible to close the openings by dumping sand and gravel, finishing this work by hydraulicking silt or mud over the area, and washing this in with a hose. By thus piling up finer and finer material and distributing it, the seepage or percolation through the rock mass was quickly checked and the barrier became effective.

The next step after having turned the water back into the main channel was to perfect the great dam of loose rock and gravel, covering it up with a mass of earth and protecting this in turn by gravel, so that the burrowing animals could not make holes through the bank and thus afford opportunities for the water from the floods to undermine the finished work.

As now completed, there extends from the head works in the United States along the river, between it and the canal, a double row of dikes, the outer one being occupied by a railroad. These extend in an unbroken line for a dozen miles near the river and shut it off from the lowlands to the west. The river side of this dike is protected by a thick layer of gravel, and the railroad affords immediate access to all parts, so that if menaced by the cutting of the banks it will be possible to bring men and materials to check the floods from encroachment upon the dike itself.

Secondary dikes or cross levees run from the main structure to certain subsidiary works, so that if the outer main dike is broken or water flows through, this will be ponded for a while at least against the inner line of defense, thus affording time to assemble the necessary equipment to fight another intrusion.

The water needed for the irrigation of lands in the Imperial Valley comes through the permanent head works in the United States, follows down behind the dikes in the channel dug for the purpose and then passes down the bed of the Alamo, enlarged during 1905 and 1906. It continues to a point where it is diverted into the canals of the settlers as before described.

The immediate danger of any further breaks appears to be done away with, although there are rumors from time to time that water

is breaking over the dikes at the head of the Paradones and following this channel is making its way into Volcano Lake, whence some of the stream turns north into the Salton Sea. It is presumed, however, that only enough water will be taken directly from the Colorado River to irrigate the land of the farmers and that no water will come to the Salton Sea except that which escapes by seepage from the cultivated areas of Imperial Valley.

EVAPORATION FROM THE SALTON SEA.

Assuming that the direct flow of the Colorado River can be checked and that no water comes indirectly through Volcano Lake, it is possible to use the Salton Sea as a great evaporating pan for the measurement of the amount of evaporation in this arid region. A knowledge of this factor is very valuable in establishing data upon which to place estimates of the amount of water which may be lost from reservoirs and other hydraulic works. The Weather Bureau is therefore attempting to utilize the Salton Sea for this purpose, and with a knowledge of the amount of water which is passing into the sea and by making corresponding deduction is noting from day to day the net evaporation or loss of water from the surface. Very delicate observations are being made of the humidity, rainfall, temperature, and other factors which influence the amount of evaporation.

FUTURE HISTORY.

It is assumed that the area of the sea will rapidly contract and that its waters will fall by loss through evaporation at a rate of 5, 6, 7, or more feet per year. The precise rate as above stated is one of the things on which more definite information is needed and one which will require careful observation and study to eliminate the conditions which disturb accurate measurements.

For many years, however, the sea will probably be a landmark of great interest to the overland traveler, and while it has no discernible influence upon the climate in general, it will serve to ameliorate the condition of overland travel through the desert. After the long hot ride, it is very refreshing to skirt the shore of the Salton Sea (Pl. IX) and glide along in the train beside the little sandy beaches or across the arms of the sea spanned by railroad bridges.

The water near the inlet has been relatively sweet, and fish from the Colorado River have come down as far as the lake. The great body of water, however, is distinctly saline or brackish and, as evaporation proceeds, will become more and more salty. It is a matter of conjecture, however, as to whether the sea will ever within the lifetime of anyone now living return to its former small dimensions or will afford again a field for the manufacture of salt.

THE SALTON SEA.

From the Salton Railroad Station, 205 feet below sea level. August 29, 1906.

The amount of seepage which will come from the cultivated fields can at present only be guessed, although with very careful cultivation this could be at a minimum. With careless use of the water, however, or with attempts to wash alkali out of the soil there will undoubtedly be a considerable amount of water wasted and this may find its way to the sea by surface channels or by slow percolation through many strata.

In riding along the present seashore it is possible to discern with favorable light the ancient sea beaches at higher levels which mark the various stages at which the water has stood in past geologic times. Some of these beaches are very plainly marked and in many localities sea shells are found in great abundance. The soil below the ocean level is of the character that might be expected in the bed of an ancient lake. Some of it is sandy and loamy and of excellent quality for cultivation. In other places, however, there are vast expanses of clays, some of these highly charged with alkali and the stiff adobe is not easily subdued for agriculture. With patience, skill, and some capital it has been found possible to produce good crops on most of this land, and, in spite of the high temperature resulting from low altitude and low latitude, modern civilization is developing and a high degree of cultivation is attained. The future of the valley as a whole will always be a matter of deep interest because of the difficulties to be overcome by the inhabitants and the constant guard which they, like the people of Holland, must maintain against the attacks of a tireless antagonist, seeking at the most unexpected times to effect an entry into their homes.

INLAND WATERWAYS.[a]

By GEORGE G. CHISHOLM.

With the exception, perhaps, of the subject of national characteristics, there is probably no subject on which it is easier and more tempting to generalize rashly than that of transport. And yet the subject is extremely complex. A very great variety of conditions have to be taken into account in determining what is really the most advantageous mode of carriage for any class of goods. In the present paper it is my duty to bring into relief the considerations of a geographical character that affect the problem. But that does not imply that other than geographical considerations are to be left out of account. In no geographical investigation whatever is it possible to proceed without any regard to considerations which must be deemed nongeographical. Even in the surveying of a country for mapping some nongeographical facts are always tacitly, if not expressly, assumed as determining the selection of the superficial features that are to be laid down. Nongeographical considerations are still more obvious in determining the degree of importance belonging to certain facts of local distribution. It is solely, for example, on nongeographical grounds that a high degree of prominence must always be given in geography to the study of climate. The nature of the nongeographical considerations that have to be borne in mind in special investigations varies with the nature of the subject. The subject of the distribution of plants cannot be handled without regard to facts which belong to the sphere of the botanist, that of animal distribution without the knowledge that belongs to the zoologist.

In considering this subject, therefore, even from a geographical point of view, it is necessary to begin by pointing out the more important facts of a nongeographical character that have to be taken into account in dealing with the geography of the subject, that is to say, in showing or endeavoring to show how far the utility of inland waterways is affected by local conditions and place rela-

[a] Paper read before the Royal Geographical Society, February 25, 1907. Reprinted, by permission, from the Geographical Journal, July, 1907.

tions. It is a group of facts that cannot be called geographical that must determine what local conditions and what place relations are of most importance with reference to the question.

Now, it is fortunate that we are in a position to recognize one important circumstance that greatly simplifies the discussion. In this country, and in all advanced commercial countries, the question is always discussed, at least avowedly, as one of economy. It is not so everywhere, nor has it always been so in our own country. In the part of the Yangtse River where the rapids occur, the substitution of river steamers or a railway for native junks is resisted by many Chinese on the ground that the numerous Chinese trackers who get a meager living by doing some of the hardest work in which human beings can engage would thereby be deprived of that living. I think I remember to have read that a similar objection to new means of transport caused the boatmen of Loch Lomond to break up the first steamboat that was launched on that lake. But we have now got beyond that stage. Such considerations are no longer taken into account in the discussion of rival modes of carriage. The question is one of economy and economy only.

But great difficulties remain. Economy in transport is not determined by the mere difference in the money cost of conveying goods, say, from one town to another. The economy to be considered with reference to transport is that of carrying goods from the place of origin to the place of consumption—the carriage of coal, for instance, from the mines to our hearths, or of wheat from the wheat fields to our tables in the form of loaves, for the place where the loaf is to be eaten has an important influence in determining where the wheat is to be ground into flour.

Those who think only of carriage from one point to another are much impressed with such figures as these. On an ordinary good wagon road a single horsepower will draw about 3,000 pounds at the rate of 2 miles an hour, on a railway about 30,000 pounds at the same rate, on water as much as 200,000 pounds. When it is considered, moreover, that the ratio of the paying load to the dead weight is higher in ships and boats than in road and railway wagons, the advantage in favor of waterways seems overwhelming. Yet these figures are far from settling the question. First, there is the consideration of time. In most cases a speed of 2 miles an hour is not to be thought of. Quickness of transport is becoming every day more important. It is obvious that with rapid means of transport a given amount of capital is more frequently turned over in any business, and manifestly, too, this must be a more important consideration the greater the value that is locked up in the goods carried. Now, by water transport, even under the most favorable conditions, it is now-

s more costly to develop a high speed than it is by land, and there

are very few inland waterways that offer those favorable conditions. Still, speed is not equally important in all cases. The greater the bulk of the goods in proportion to their value, the heavier will be as a rule the relative cost of carriage, the more important, therefore, a money saving in transport charges, and the less urgency to that extent for economizing merely in time.

But, further, even in considering different methods of transport between two points on which a waterway is available, it must be borne in mind that great economies in transport are secured by carrying goods in great quantities. It is for this reason that British shippers keep building larger and larger numbers of large ships and increasing the size of those ships, and Americans keep building more and more powerful locomotives for the hauling of long trains composed of huge steel wagons built as light as possible in proportion to the load they carry. On this ground the utility of a waterway must depend very greatly on its capacity.

Again, only a comparatively small quantity of goods can be conveyed direct by one means of transport from the point of origin to the place of consumption or utilization. They have mostly to be transferred from one vehicle to another. This necessarily involves cost. The cost varies greatly with the nature of the commodities handled, but in all cases it makes it important to avoid this handling as much as possible. In a report advocating a great scheme, which I shall have occasion to refer to again in this paper, it is stated that "a ton of coal is carried the thousand miles from Buffalo to Duluth for about the cost of shoveling it from the sidewalk into the cellar;"[a] and though I would not be understood to hint that when coal is handled on a large scale, the cost of handling approaches the cost of finally putting it in the cellar, still this statement is a significant reminder of the importance of this element in the cost of carriage. The advantage to Germany of being able to communicate by rail without break of bulk with all surrounding countries except Russia (where there is a different railway gauge) can be abundantly illustrated from the commercial statistics of that country. It was to secure this advantage that great railways were built across and partly through the Alps, and the numerous trains to be seen even in central Italy (how far south I can not say from my own observation) containing wagons that have come, if we may judge from the inscriptions on them, both from Austria across the Brenner and from the Rhine valley through the St. Gothard, are a speaking illustration of the same thing. The St. Gothard tunnel had a very speedy effect in developing a trade, even in heavy iron goods, between Germany and Italy, and German coal has been carried into Italy as far as Milan,

[a] This is no exaggeration. The average freight for hard coal from Buffalo to Duluth in 1904 was about 1s. 6d. per long ton; in 1905, about 1s. 10d.

though whether that trade is still carried on I am unable to say. Through the courtesy of the Intercontinental Railway Company and of Mr. Ernest de Rodakowski, author of "The Channel Ferry," an extremely interesting and instructive work written to advocate carrying on trade without break of bulk between this country and the continent by a method not open to the objections urged against the proposed Channel tunnel, I am able to illustrate this important point by some lantern slides which, I think, will speak largely for themselves.

The first shows how the trade in imported meat is carried on between Southampton and London. The meat, on being taken out of the importing ship, is transferred, not to railway trucks, but to lorries or road wagons mounted on the trucks. Each truck is capable of carrying 10 tons, but as the pair of lorries has a weight of between 3 and 4 tons, it is clear that there must thus be a considerable addition to the dead weight hauled, even though the trucks are reduced to a simple platform mounted on wheels, and on the return journey to Southampton the whole train is dead weight, as no suitable freight for the carts can be found. Yet the mere saving in handling has caused this mode of transport to be carried on with satisfactory results to the company for about seventeen years.

My second illustration is one of a channel ferryboat, such as was familiar to me in my boyhood in the early sixties as plying between Granton and Burntisland under the name of "leviathans." The width of the crossing effected by those boats was only 5 miles, but since then the same method of transport has been adopted for crossings up to 96 miles (the widest being from Ludington to Milwaukee, on Lake Michigan). The present view shows the *Solano* on the passage from Oakland to San Francisco, a boat which carries on its four rail tracks twenty-seven passenger cars or forty-two goods wagons of the ordinary large American type.

The third illustration shows the method by which the trucks are landed on the Warnemünde-Gjedser route between Germany and Denmark, opened on October 1, 1903, with reference to which I am able to give some particulars of direct significance regarding the subject now in hand. In the first place, I am informed that the wagon marked "Breslau" actually came from Breslau, a distance of some 350 miles from Warnemünde, 375 miles from Gjedser, and 480 miles from Copenhagen, for which it was not improbably destined. Now, if it was for Copenhagen, that was a journey on which an all-water route was available, first by means of a river accommodating boats of 400 tons burden to Stettin (305 miles), and then by seagoing vessels. Yet the rail route was preferred. On one occasion on which Mr. E. de Rodakowski accompanied the train, only six minutes elapsed between the arrival at Warnemünde and the departure of the steamer. The goods carried on that occasion were chiefly angle

iron, and I am informed by the London agent of the Intercontinental Railway Company that in the first nine months after the opening of this route 14,000 trucks and 60,000 passengers were conveyed by it; and since train ferries were first opened for traffic in Denmark, many new industries have been developed to a considerable extent, and heavy machinery, glassware, etc., which in former years were imported into Norway, Sweden, and Denmark from England, are now being sent from Germany on the ferry steamers.

It is the balance of advantage determined by the two considerations mentioned, the economy of carriage on a large scale and that arising from the conveyance of goods as directly as possible from the place of origin to their destination, that determines in many cases the mode of transport. It is the advantage of transport on a large scale that causes from 40 to 70 per cent of the pepper, 50 to 60 per cent of the rubber, and large proportions of a great many other articles imported into this country to be reexported as they arrive, that causes raw cotton (Egyptian) to be always one of the leading exports from this country to the United States, and causes Belfast to export directly to foreign countries (or rather to one foreign country) a greater value of raw cotton than all British and Irish goods (including ships) put together. On the other hand, to illustrate the advantage of carrying goods as directly as possible from the place of origin to their destination, I may mention as a typical case that of a paper mill which I remember to have existed near an east coast fishing station, not important enough to be entered in the tables of British ports, which got all its supplies of China clay and esparto in small schooners entering the fishing harbor after voyages lasting for weeks from Cornwall and Algeria, respectively. The goods were thus brought within carting distance of a mill which could use the entire cargo. To take a case more immediately cognate to the subject under consideration, the same reason explains why so much English coal for domestic use is carried long distances by rail in comparatively small wagons. It is in that way, and probably in that way only, that convenient lots of the different qualities of coal required can be brought direct from the mines within easy carting distance of everybody's coal cellar.

Now let us apply these general considerations on the subject of transport to inland waterways and the geographical conditions affecting their utility.

It will now be manifest that inland waterways are likely to be most effective in securing traffic—

1. The greater their capacity.

2. The greater the distance for which they permit of that economy in transport which is due to easier haulage or propulsion.

3. The more direct they are between any two points between which there is a competing means of transport.

4. The more favorable they are to rapid haulage or propulsion, a condition which, for the sake of clearness, it is well to discriminate, even though the advantage under this head is almost inevitably associated with high capacity.

5. The freer they are from such differences in level as necessitate the use of locks or other lifting and lowering contrivances, this being important, not merely in consequence of the loss of time in locking or otherwise changing the level, but in consequence of the additional expense, which varies with circumstances, being in many cases enhanced by the necessity of supplying locking water artificially, or by the impracticability of making locks of large capacity.

6. The smaller the impediments to navigation due to rapidity of current, or the occurrence of low or excessively high water, or ice.

7. The greater the amount of commodities, at once heavy and bulky in proportion to their value, procurable at some point or points on or near the waterway and consumed at other points similarly situated.

8. The less the expense involved in the handling of commodities, including any expenses arising from damage or the risk of damage to the commodities. All kinds of coal suffer more or less in the severe handling involved in the use of waterways, but the softer kinds, of course, suffer most. While there is an enormous trade in coal on the Great Lakes of North America, coke, it is said, will not bear this mode of transport at all on account of the damage involved. Earthenware and glass may be conveyed undamaged in spite of the rough handlings to which they are exposed in water transport, but the extra care required in packing adds to the expense, and even then the risk adds to the insurance.

9. The smaller the opportunity there is for railway or other competition. Railway competition is particularly formidable, not only because "the hard smooth road" (to adopt the description which Professor Jevons applied to a railway) allows of far quicker transport than can be effected by any other means, but also because railways with their numerous interramifications offer the possibility of transport without break of bulk to a much greater extent than any system of inland waterways can approach.

If time permitted, illustrations might be given of the special importance of several of these factors in promoting the use of inland waterways; but time does not permit, and I will only say that it seems to me, from the examination I have given to the subject, that if any one of the nine can be singled out as the most decisive in furthering inland water traffic, it is the seventh—the existence of

great quantities of bulky produce to be taken up and delivered at individual points on the same or a connected waterway. And yet, singularly enough, by far the most important article of commerce on the most magnificent system of inland waterways in the world is one of great value and small bulk. I refer to the rubber trade of the Amazon, which, it may be remarked, is a water trade solely because there is too little opportunity in that region for trade in bulkier commodities to justify the introduction of railway competition.

In order to realize the possibilities of inland water traffic it will be well to examine in the light of the foregoing considerations what has actually been done under some specially favorable conditions. For this purpose I am able, through the courtesy of Messrs. Longmans, Green & Co., to show a map of the German waterways,[a] which to a large extent speaks for itself. It may be added that the improvements sanctioned by the act of April 1, 1905, are intended to provide waterways on all the sections indicated west of the Oder for barges of 600 tons, on those east of the Oder for barges of 400 tons.

Of all the waterways shown on this map there is probably none more worthy of study than the Rhine. It has peculiar advantages under all the heads mentioned except the last, and there is something to be said on the last head also, that is, with regard to the nature of the competition it encounters. It is (1) capacious enough to be regularly ascended by fairly large seagoing steamers as high as Cologne, by smaller seagoing vessels as high as Remagen, about midway between Cologne and Coblenz, and occasionally as high as Oberlahnstein, on the left bank of the Lahn above Coblenz, where they go to load with mineral water. Since the improvements in the gorge at Bingen were completed in 1899, barges of more than 2,000 tons have been known to reach Mannheim, and those of 800 tons can reach Strassburg. (2) The distance of Mannheim from Rotterdam by water is 351 miles. The river in a large part of this stretch is (3) remarkably free from windings. The river distance is only 41 miles, about 13 per cent, greater than that by rail. (4) Powerful steamers can be used for carriage or haulage. (5) There are no locks as high as Strassburg, the present limit of Rhine navigation. There is only one to Frankfort-on-Main. (6) Below Strassburg the rapidity of the current of the Rhine offers no serious hindrance to navigation, except perhaps in the narrowest part of the channel at the gorge of Bingen, though it is everywhere sufficient to make a marked differ-

[a] With regard to the French and Belgian waterways shown in this map, it should be stated that those drawn in thick lines are those with a minimum depth of 2 meters, and that not all of these are navigated by barges of as much as 400 tons.

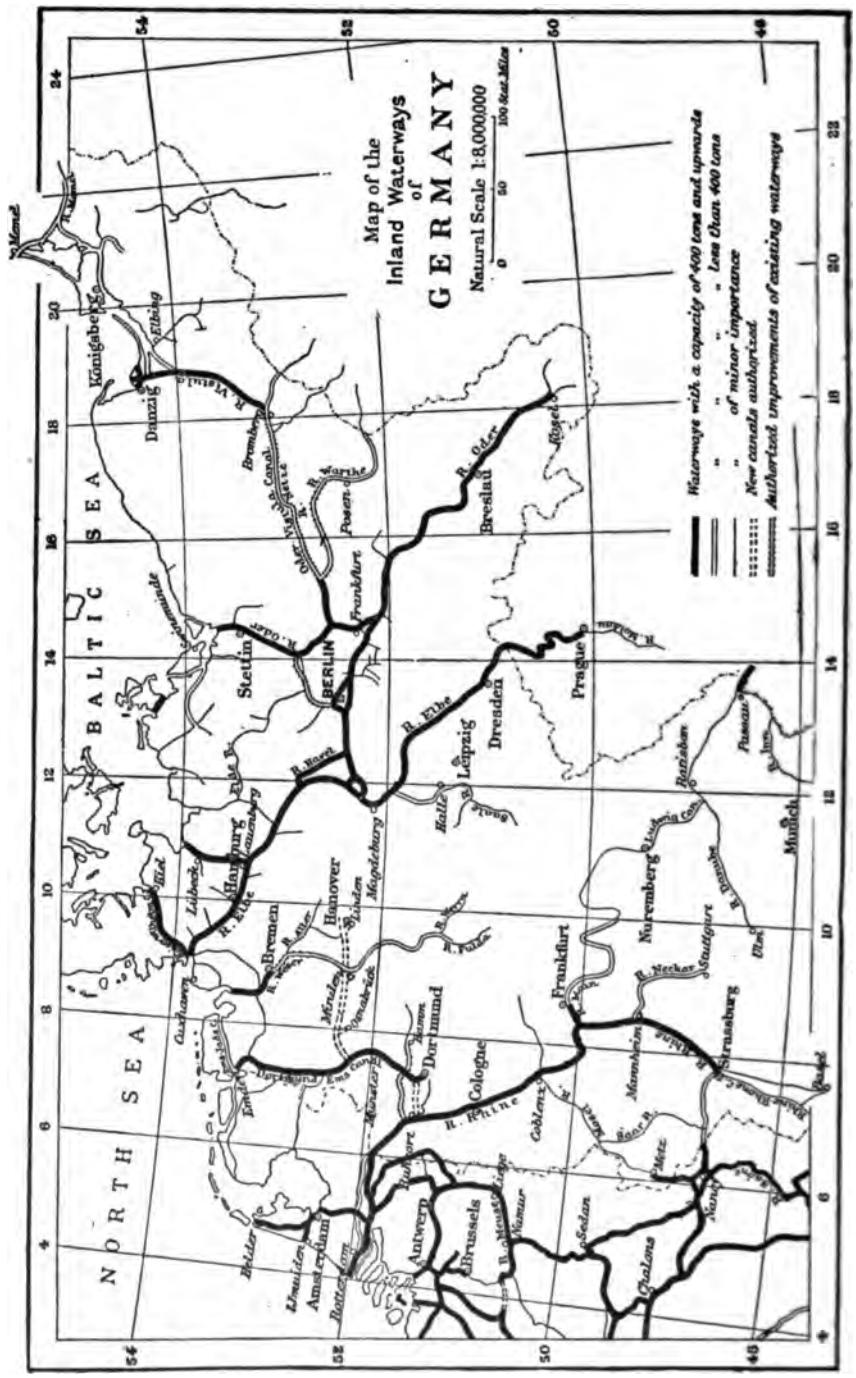


FIG. 1.—Inland waterways of Germany.

ence between the rate of upstream and downstream navigation.[a] The geographical conditions also tend to reduce the interruptions to navigation, from irregularity of flow and from ice. The fact that the upper Rhine is partly glacier-fed and lake-regulated tends to limit the variations of high and low water, and the westerly situation of the river is against its freezing. According to an official publication, the navigation of this river "is, on the average, annually interrupted by high water for 8 days, by ice 17 days, by low water 17 days; in all, accordingly, 42 days."[b] (7) At the mouth of the Rhine is Rotterdam, a world port, and accordingly a great collecting point for all kinds of commodities, bulky and other. On the banks of the river within Germany, up to and including Strassburg, there are ten communes with a population exceeding 50,000, five of these with one above 100,000, and to these may be added Frankfort, all great consuming centers at least for imported grain. Further, the river actually divides, below the point to which seagoing steamers regularly ascend, the most productive coal field on the mainland of Europe, and this fact creates a demand for enormous quantities of imported ores. (8) Among the commodities grain is one that notoriously can be handled with peculiar facility, and ores, too, are comparatively inexpensive to handle. The German coal is, indeed, more likely to be damaged by handling than the harder English coal, but this is not enough to invalidate the overwhelming advantages of the Rhine for a trade in coal of local origin.

These considerations may serve to prepare one for the figures given below, stating in thousands of metric tons (each 2,205 pounds) the total traffic on the Rhine at Emmerich, close to the Dutch frontier, at the adjacent harbors which serve as the outlets of the Ruhr coal field, and at Mannheim, the terminal point of navigation for the larger craft.

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[a] Some details may be of interest. The average speed of a train of four barges, carrying in all about 4,000 tons, is given at 3 to 3¾ miles upstream and 9 to 11 miles down. When the necessary night rests are allowed for, the voyage from Rotterdam to Mannheim is made in summer in from 8 to 9 days, in winter in from 10 to 11 days; that from Mannheim to Rotterdam, in either case, in about 5 days. Express goods steamers, stopping at intermediate stations, ascend from Rotterdam to Cologne (190 miles) in about 36 hours = 5.6 miles an hour, and descend on the return voyage in about 19 hours = 9.3 miles an hour. On the rare occasions on which a long voyage is made without stoppages, a speed of 5.3 miles an hour may be attained between Cologne and Mannheim (161 miles), and one of 13.7 miles an hour between Mannheim and Cologne. Nasse, in "Die Schiffahrt der deutschen Ströme," herausgegeben vom Verein für Socialpolitik (Leipzig, 1903), vol. 3, pp. 142–143.

[b] Jasmund, "Die Arbeiten der Rheinstrom-Bauverwaltung von 1851 bis 1900," p. 54; quoted by Nasse in the work just cited, vol. 3, p. 138.

Year.	Emmerich.		Ruhrort, Duisburg, and Hochfeld.		Mannheim.
	Passed up.	Passed down.	Dispatched up.	Dispatched down.	Arrived up.
1895	4,880	3,048	3,446	2,005	2,436
1900	9,036	4,130	6,225	2,370	3,917
1903	10,028	7,211	7,154	4,615	4,251
1905	12,533	8,119	6,172	4,125	3,942

For the sake of comparison, it may be mentioned that the total quantity carried by the Manchester Ship Canal in 1905 was 4,250,000 tons.

And now let us see how these totals were made up. In 1905 the quantity of iron and other ores that passed upstream at Emmerich was 5,352,000 tons; that of wheat and other grains of the temperate zone, 3,250,000 tons—in all 8,602,000 tons, leaving only 3,930,000 for all other commodities. Coal made up more than half the quantity that passed down. At Ruhrort, etc., coal made up 5,940,000 tons of the 6,172,000 tons sent up and 3,492,000 out of the 4,125,000 tons sent downstream. At Mannheim coal and grain together constituted nearly two-thirds of the total quantity received. The quantity of goods sent downstream was comparatively small—660,000 tons, of which salt formed the most important item.

It is instructive, also, to note some of the commodities carried by water in smaller amount, and for that purpose I have selected four of the raw materials according to the classification of the official report on the inland waterways of Germany. In this case I have taken the Rhine and the Elbe together as the water avenues to the chief manufacturing districts of the empire.

Imports in 1905 in thousands of metric tons and one decimal of a thousand tons, with the percentage imported by water of the total import.

	By Rhine and Elbe.	Total.	Percentage by water.
Raw cotton	73.9	402.9	18
Raw wool	40.4	165.1	24
Flax, hemp, and tow	70.2	140.6	50
Hides, skins, peltries, and leather	27.7	170.3	16

The only one of the four of which a large proportion is carried up by water is flax and hemp, and this may be accounted for in two ways—first, by the fact that this is much the least valuable of the four in proportion to its bulk; and, second, that the Elbe, by which the bulk of the import takes place, carries this commodity such a long distance on the way to the chief seats of manufacture in the eastern part of the Kingdom of Saxony, the adjoining districts of Silesia, d the Austrian province of Bohemia.

The water traffic of Berlin is also instructive. At last census the population of Berlin was upward of 2,000,000. The city is connected by waterways with the ports of Hamburg and Stettin, and upstream with the river port of Kosel, in the vicinity of the Prussian coal field, which ranks next in importance to that of the Ruhr basin. The Hamburg route has been navigable since 1894 for vessels of 600 tons burden, and on that route there are only three locks. The waterway up to Kosel has been available since 1897, in ordinary states of the river Oder, for barges of 400 tons. Owing to the comparatively small depth of the Finow canal, at present 4¼ feet, and the number of locks upon it, 17, the Stettin route is the least commodious of the three. In 1905 the total quantity of goods, including floated timber, delivered at Berlin by water, was 7,364,000 tons; and it is noteworthy that the total quantity dispatched was less than one-eleventh of that, even though the shippers must obviously have every inducement to take return freight at the lowest possible rate. Of the goods delivered, those entered under two headings: (1) Bricks, tiles, pipes, and other articles of baked clay, and (2) earth, loam, sand, limestone, and chalk, made up more than 57 per cent of the total. These commodities are almost entirely of local origin. The third commodity in respect of percentage is coal, and the addition of it brings up the total proportion belonging to the first three commodities to nearly 73 per cent. The coal is partly Silesian, partly English, but in spite of the advantages afforded by the Oder, in 1901 only about 35 per cent of the Upper Silesian coal sold in Berlin and its suburbs arrived by water.[a] In recent years the quantity of English coal reaching Berlin by Stettin and the Finow canal has been greater than that arriving by water from Silesia, in spite of the inferiority, and consequently greater expense, of the Finow route; one important difference in favor of the Stettin-Finow traffic being that the English coal necessarily arrives at the waterway in bulk, and has not to be brought down to it like the Silesian coal from the several mines. The coal brought to Berlin from Upper Silesia is chiefly for use in the large works alongside the waterways. For the reason already indicated, domestic coal comes mainly by rail. The same reason that keeps down the proportion of coal using the waterway from Silesia to Berlin causes the great bulk of the Westphalian coal that comes to Hamburg to go by rail. Even the opening of the Dortmund-Ems Canal, which was constructed expressly for the purpose of providing a water outlet for the coal of the Ruhr basin, has done little to develop that trade. The total quantity of goods carried down that waterway to the port at its

[a] 'Die Störungen im deutschen Wirtschaftsleben während der Jahre, 1900 ff.,' 2ter Band, Montan und Eisenindustrie (Leipzig: Duncker & Humblot, 1903), p. 157.

mouth (Emden) in 1904 was just under 190,000 tons, of which 97,000 tons was coal; in 1905, 224,000 tons carried down, of which 68,000 tons was coal. Upstream from Emden there passed, in 1905, 475,000 tons, of which 258,000 tons consisted of iron ores.

Those who advocate the improvement of existing waterways and the construction of new ones very often lay great stress on their value as a means of carrying local agricultural produce and manufactured goods specially for export. It will, therefore, be worth while to consider what is achieved by the German waterways under these heads. For the consideration of the efficiency of waterways as carriers of agricultural produce, Germany affords no better subject of study than the great consuming center of Berlin. Elaborate tables[a] drawn up in a work already quoted, written in the interest of the German waterways, enable us to make comparisons on this head. The raw agricultural products most largely carried by water to Berlin are the chief bread grains of Germany, rye and wheat, and, on the average of the years 1896–1899, about 69 per cent of these were received by water, and about 31 per cent accordingly by rail. But nearly all this was foreign grain collected at the seaports. A different tale is told by the figures relating to potatoes. In 1899 the proportion conveyed to Berlin by water was less than 2 per cent. In fact, an examination of the data regarding the trade in agricultural products generally bears out the truth of the general statement made in the work just cited,[b] that "the raising of agricultural products always presupposes a relatively extensive area of production, and is thus a decentralized industry, on which account, in the great majority of cases, it is only the railways that come into consideration with reference to their transport."

Of manufactured articles carried by waterways, the only one of importance as regards quantity, except on the Elbe, on whose banks there are large centralized industries concerned in the refining of sugar and the manufacture of fertilizers, are iron and iron wares. Now, in 1905, of the raw and scrap iron conveyed to the seaports or across the German frontier, only about 25 per cent was carried by water, 75 per cent by rail, and all but a small fraction of the quantity carried by water went by the Rhine, that carried by the Dortmund-Ems Canal being utterly insignificant. Of the iron and steel manufactures of all kinds similarly carried, the share of the waterways was about 40 per cent, that of the railways 60 per cent, and in this case again the share of the Rhine made up the great bulk (more than 95 per cent) of the total water-borne traffic. That of the Dortmund-Ems Canal was little more than 2 per cent.

[a] 'Die Schiffahrt der deutschen Ströme,' vol. 1, pp. 185 and 238–245.
[b] *Vol. 1, p. 152.*

So far we have considered only the really effective waterways of Germany, but some of the minor ones are also worthy of attention. For example, there is the celebrated Ludwig's Canal, a waterway 5 feet deep, connecting, with the aid of other waterways, the Rhine and the Danube. What does it do? It carries on a trifling and dwindling amount of traffic, chiefly centered, as is natural, at Nuremberg, where, in 1905, the total quantity of goods received and dispatched by it in both directions was much under 50,000 tons. At Kelheim this canal passed into the Danube 4,637 tons of goods, chiefly timber; from the Danube toward the Main, 676 tons. Then there is the Ruhr, which flows through the great German coal field to the Rhine, and can take barges of 165 tons—that is much larger than the great majority of English waterways. In this case it is worth while noting what it once did, as well as what it now does. In 1860 it carried in all 900,000 tons of goods, of which coal made up 868,000 tons. In 1905 it carried 1,431 tons of stone downstream, and nothing up.

The result was due to railway competition, which comes under the ninth of the geographical considerations above enumerated as affecting the utility of waterways. And now it may be remembered that this is a subject on which, I have intimated, something remained to be said in connection with the traffic on the Rhine. That traffic is carried on against a good deal of railway competition. In the narrower part of the Rhine valley there is a double line of railway on either bank of the river, and there are more railways running in the same direction higher up. But the competition is not equal, I mean not based solely on the merits of the two methods of transport. For, in the first place, the German state railways are admittedly not worked on the principle of offering the most effective opposition possible to the waterways; and, on the other hand, the states adjoining the Rhine have spent some £8,000,000 in bringing the navigation of the river to its present condition, and have handed over the river to the shippers free of toll. And yet even under these conditions some of the shipping companies in a recent period had very bad times. In 1902 eight out of nineteen companies paid no dividend. In 1903 four paid none. Under the recent act for the improvement of the waters it is declared that when those improvements are carried out, or rather when the Rhine-Weser Canal or a section of it has been brought into operation, all those rivers on which the state has spent money in the interest of the navigation shall be subjected to such tolls as shall serve to pay a suitable rate of interest on the outlay and something toward the amortization of that outlay. This enactment has caused many of those who insist most stoutly on the advantages of water transport to cry out with dismay that the rivers will not be able to stand such a burden. "For the human soul," says George Eliot, "is

hospitable, and will entertain conflicting sentiments and contradictory opinions with much impartiality."

Let us now turn to America. The experience of that part of the world is not without instruction for us, even though the conditions under which most of the inland water traffic is there carried on are even more unlike those in our country than the conditions in Germany. The bulk of that traffic is the traffic of the Great Lakes, and so far as that is confined to the Great Lakes it corresponds, not to our inland water traffic, but to our coasting trade. By far the greater proportion of it is so restricted. But the Great Lakes also form part of two waterways from the interior to the seaboard, one Canadian and the other belonging to the United States. The Canadian is of course that of the St. Lawrence, leading to Montreal, and has peculiar advantages for carrying on an export trade in grain. Since the completion, in 1899, of the improvements on the St. Lawrence there has been a minimum depth of 14 feet on the entire waterway. At the head of the route are the enormous grain—above all wheat—collecting points of Fort William in Canada and Duluth and Chicago in the United States. But as against these advantages it has to be remembered that the route is closed by ice for about five months or more every year. In spite of this drawback the waterway carries on an average much more than half the grain carried eastward to Montreal. In the thirteen years, 1893 to 1905, the water-borne proportion varied from 83 to a little more than 47 per cent, this minimum having been the limit of a regular decline in the proportion of grain so carried from 1895 to 1901. By 1905 the proportion of water-borne grain had risen again to nearly 72 per cent, but in this we may probably see the effect of the abolition, in 1903, of tolls on all grain carried through both the Welland and the St. Lawrence canals, though a toll of 10 cents (say 5d.) a ton is still levied on all grain that passes through the St. Lawrence canals only. The meaning of this discrimination obviously is that on the heavy long hauls the railway is able to offer very effective competition even with this advantageous waterway.

The success of this waterway has long ago inspired the Canadians with the idea of taking advantage of the geographical conditions to create a more effective waterway, offering the recommendations both of a shorter route and greater depth. This project is what is known as the Ottawa and Georgian Bay scheme. The promoters of this scheme urge that by deepening in places the river Ottawa, by utilizing Lake Nipissing and its outlet the French river leading to Lake Huron, and by constructing the necessary canal connections, a waterway running nearly due west from Montreal would be substituted for that which first ascends a long distance to the southwest and then *turns northward.* In that way a saving of about 340 miles in the *voyage to and* from the higher lakes would be saved. Further, of

the total length of 425 miles on this new route 307 miles would be made up of river and lake navigation needing no improvement to admit of its being navigated by vessels of 20 feet draft. A committee of the Dominion Parliament has recommended the carrying out of the scheme and the adoption of a depth of 22 feet for the whole route. One drawback, however, is unavoidable on this proposed route. In consequence of its northerly situation, there would be only a very short season after harvest in which it would be free from ice.

The United States waterway which continues to the seaboard the navigation of the Great Lakes is the Erie Canal with the Hudson River. This has the advantage of being connected with a much more important seaport than the St. Lawrence route, but, on the other hand, is much inferior as a waterway. It has at present a depth of only 7 feet, and the maximum size of the barges which make use of it is only about 250 tons. In this case, accordingly, we find that the railways are able to compete with the waterway much more effectively than in Canada, even though the canal is maintained by the State entirely free from tolls. On this head, however, one instructive difference may be noted between the practice in Germany and that both of Canada and the United States. In these two countries the railways that compete with the waterways are all private undertakings, and do all they can to compete with their rivals in the most effective manner. The result is that of the total amount of grain carried to New York in 1905 about 93½ per cent was transported by rail as against some 6½ per cent by water. In recent years, the actual quantity of goods of all kinds carried by the Erie Canal has greatly diminished—from a maximum of 4.6 million tons in 1880 to less than 2 millions in 1904. And this was mainly made up of local traffic. The amount carried by the canal to tide water in that year was considerably less than one million tons. In 1880 all the canals of the State of New York carried rather more than 25 per cent of the total traffic of the State, in 1904 less than 5 per cent. In order to restore, if possible, the efficiency of the waterways, the State is now spending about

FIG. 2.—Inland waterways of Illinois.

£21,000,000 in making a canal with branches with a depth of 12 feet, and capable of accommodating barges of 1,000 tons, on the routes shown on the accompanying map.

Of the natural inland waterways of the United States, in addition to the Great Lakes, the Mississippi offers advantages for traffic of a kind to which not merely our own country, but the whole continent of Europe, can offer no parallel. Yet it is a very striking fact that even on these the ordinary steamer traffic has shown a great decline. No general statistics have, I believe, been collected since 1889, but the Tenth and Eleventh censuses of the United States allow of a comparison being made between the total traffic of 1880 and that of 1889, between which years the total amount of traffic carried on steamers in the Mississippi valley generally sank from 13.6 to 10.3, that on the

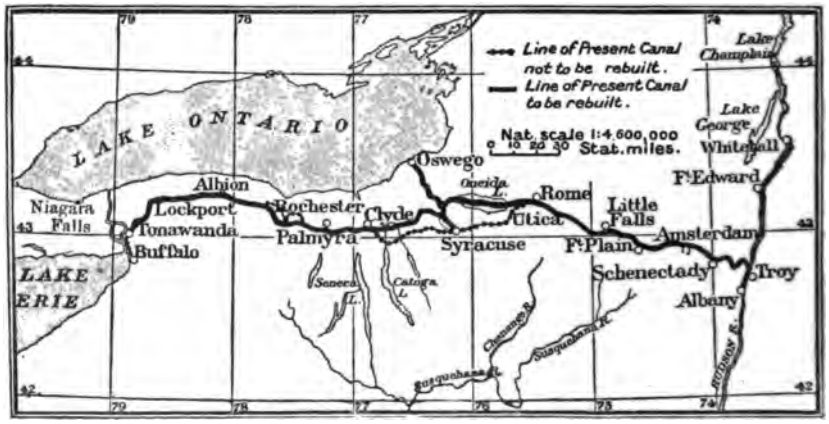

FIG. 3.—New York State canals constructing under a law of 1903.

Ohio from 9.2 to 3.8 millions of tons. In 1901 the total quantity of goods received at New Orleans from the interior was less than 5 per cent of that received by all routes.[a] Still, from the Mississippi and Ohio we can obtain illustrations of the kind of traffic in which good waterways are even now successful. St. Louis is a great collecting point for grain. In 1903 more than 80 per cent of the wheat and about 40 per cent of the maize dispatched thence for export to New Orleans went by river, and by this route rates for wheat on through bills of lading to Liverpool are only about two-thirds of those by way of New York.[b] Yet the facts, even of this trade, give us a hint also of what waterways fail to do, for only about one-seventh of the wheat and one-thirteenth of the maize exported in that year from New Orleans came to the port by water.

[a] See the data in the Foreign Office Report, Annual Series, No. 2752, pp. 4, 5.

[b] Foreign Office Report, Annual Series, No. 3202, pp. 48, 49.

But the grain trade of the Mississippi is largely, and the still greater coal trade of the Ohio-Mississippi almost wholly, carried on in a peculiar manner possible only in very wide, though not necessarily very deep, rivers. It is by means of what are called tow barges—that is, a number of barges firmly lashed together and pushed onward by means of a stern-wheel steamer. The coal is all brought from the Ohio and its feeders, the Monongahela and the Great Kanawha, the first of which is one of the two head streams of the Ohio which meet at Pittsburg, while the other joins the main stream in West Virginia. At Pittsburg tows of barges drawing 8 feet are made up, carrying from 10,000 to 15,000 tons of coal. They may have to wait for a sufficient depth of water before proceeding on their way to Cincinnati and Louisville. At Louisville two or three Pittsburg tows may be made into one, carrying from 35,000 to 40,000 tons. Even one of 70,000 tons is on record. One carrying 40,000 tons, Professor Johnson tells us, is about 10 acres in extent.[a] At the same ratio, one of 70,000 tons would extend over 17½ acres—say 140 by 600 yards.

It is boasted that this is the cheapest mode of inland carriage in the world, and yet even this traffic, which increased enormously between 1880 and 1889, would appear to be now declining in the aggregate, and is certainly not keeping pace with the enormous progress of the American coal trade generally. In 1889 the total amount of freight carried on the Ohio was officially returned at above 16,000,000 tons, of which tow-barge traffic made up considerably more than 12,000,000 tons. In a consular report for 1905, the total traffic of all kinds was estimated at 11,000,000 tons,[b] and the figures in the official returns for the coal trade of the Great Kanawha in recent years are at least not progressive.[c] This, no doubt, is the cause of the demand made by those interested in the Ohio navigation for the improvement of that river by the Government of the United States, so as to afford a minimum depth of 9 feet at low water, a demand to which the Government has so far acceded as to obtain from Congress appropriations for a survey of the entire river for that purpose.

But a still greater project is now being agitated, one, namely, for the creation of an uninterrupted waterway of 14 feet in depth from Chicago to New Orleans, so as to allow of loaded seagoing vessels passing from one port to the other. An association, known as the Lakes-to-the-Gulf Deep Waterway Association, has been formed to carry out this scheme, and I am informed by its secretary that its total cost is estimated at about £14,500,000. Part of the proposed waterway

[a] Emory R. Johnson, "Ocean and Inland Water Transportation" (London: Appleton, 1906), p. 364.

[b] For. Off. Rep., Ann. Ser., No. 3622, p. 35.

[c] See the Annual Report of the Chief of Engineers of the War Department of the United States for 1905, vol. 6, part 2, pp. 1886, 1887.

would be formed by the Chicago Sanitary and Ship Canal, connecting Chicago with the Des Plaines River, a canal with a minimum depth of 14 feet, begun in 1892, and now approaching completion. This canal the trustees of the sanitary district of Chicago propose to hand over to the General Government on condition that it completes the projected waterway; but when one considers that the 42 miles of this canal, when completed, will have cost about £11,500,000, the total estimate above given must surely be rather sanguine.

Such a project as this may at least serve to give an idea of the enthusiasm which inland waterways inspire in the minds of some people, but is not fitted to afford any guidance in the study of English waterways, and to these it is now time to devote attention. With reference to the special subject of this inquiry, namely, the influence of geographical conditions on rail and water transport, there are few countries, if any, in which the facts are more worthy of study than our own, seeing that in this country the two means of transport have been left to fight it out between themselves, with little interference on the part of the State. It has been the general rule in other countries, as in Germany and the United States, for the State to intervene on behalf of the waterways. In this country the only way in which the State can be said to prejudice the railways in the contest is in insisting, in the case of those canals which have become railway property, that the canals shall be maintained whether the railway can work them at a profit or not, and that the owning companies shall, at the demand of traders, quote rates subject to State regulation. I would not be understood to assert that this is undue interference on the part of the State. I merely mention it as at least a fact that should be recognized.

And here I may point out that the existence of railway-owned and railway-controlled canals in this country introduces another geographical consideration, although only of a secondary order, by which I mean one not originally given or mainly determined by nature. Once established, however, the nature of the ownership may have geographical effects, and it is at least incumbent on us to inquire whether it has such or not. For that reason several canal maps have been drawn up in which the distinction of ownership or control is indicated, and one of these I am now able to show through the courtesy of Messrs. Longmans, Green & Co. On this map, it should be noticed, the canals are distinguished, not as railway owned and independent, but as railway controlled and independent; for this makes an important difference, inasmuch as the Birmingham Canal Navigation belongs to an independent company. This, however, is a mere dividend-receiving company, the dividend being guaranteed

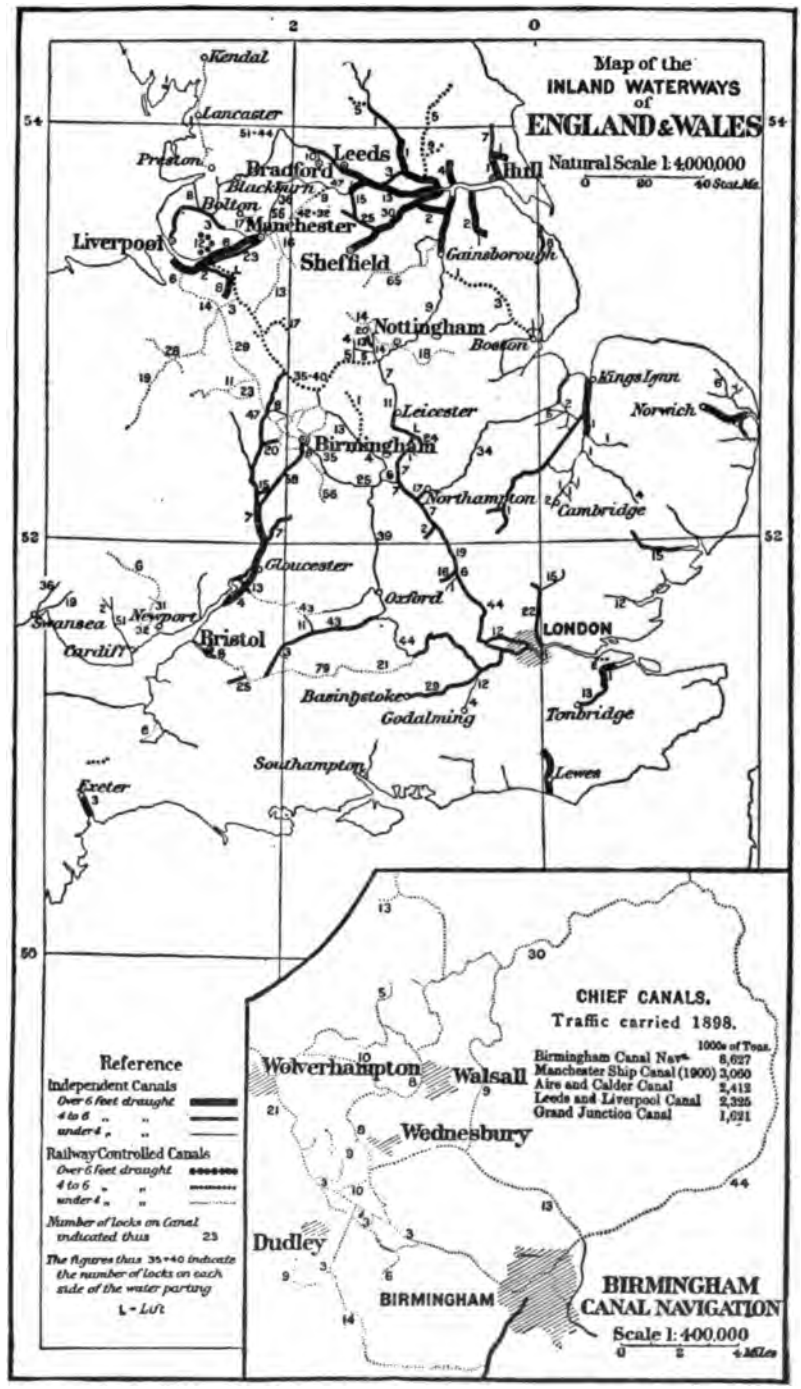

FIG. 4.—English waterways.

by the London and Northwestern Railway Company, which under an old agreement with the canal company controls the navigation.

This map also, following the well-known map of Mr. Lionel Wells, makes an attempt to distinguish the canals in respect of their capacity, and it will be noticed what a large proportion of them are small waterways of less than 4 feet in depth, many being not merely shallow but narrow and capable of being used only by what are known as narrow boats.[a]

Further, on this map an attempt has been made to indicate the effect of inequalities of level on inland navigation. In one respect the most satisfactory maps that have been published, so far as I know, giving indications under this head, are the large maps showing the waterways of England and Wales, of Ireland, and the Scottish midlands, respectively, attached to the paper "On Waterways in Great Britain," read in November, 1905, by Mr. J. A. Saner, M. Inst. C. E., to the Institution of Civil Engineers, of which the author was good enough to favor me with a copy. These maps show the waterways in relation to the physical features as indicated by contour lines and intervening coloring. It is to be regretted, however, that they do not give the number of locks on the different waterways, which the scale of the maps would have made comparatively easy. Of the difficulties presented by English canals the best idea may perhaps be obtained from the sections published in Mr. E. A. Pratt's "British Canals." On the map now shown the number of the locks on different canals and waterways, or sometimes on sections of canals, has been given in figures, but the map is on rather a small scale for that to be done quite satisfactorily. It will, however, at least serve to keep us in mind of the fact that in this respect English waterways mostly suffer from great drawbacks.

It may be worth while to examine some of the more important canals separately with reference to this point. It will be noticed that there are three waterways connecting South Lancashire with the West Riding of Yorkshire, and, accordingly, crossing the Pennine chain; two of them independent canals, the third railway owned. The most important of these is the Leeds and Liverpool Canal, the northernmost of the three, which, it will be observed, has fifty-one locks on the one side, forty-four on the other. It has, however, the easiest route of the three, going through the important feature which Mr. Mackinder has well called the Aire gap, at the height of only 477 feet above sea level. The Rochdale Canal, the next to the south, rises above 500 feet, and the Huddersfield Canal reaches its summit, 656

[a] The work affording the most complete information about English waterways under this and all other heads connected with their use is Bradshaw's "Canals and Navigable Rivers of England and Wales," by H. R. de Salis (London, 1904).

feet, in the Stanedge tunnel 3 miles long. In the Harecastle tunnel, 4 miles northwest of Stoke, the Trent and Mersey Canal attains a height of 460 feet. Birmingham is connected with the Thames by a waterway which starts at 380 feet above sea level, sinks to 180 feet in the valley of the Avon, and rises again to 390 feet where it passes through the Chilterns; and with the Severn by one starting at 425 feet above sea level, and making a rapid descent of about 250 feet in 3 miles after passing through the Tardebigge tunnel.

It has also to be noted that, in addition to railway competition, the inland waterways of this country have to encounter that of the coasting trade, and when all the drawbacks of English waterways are considered, it is not too much to say that, in proportion to their capacity as regards volume and speed, the work done by them compares very favorably with that done by the waterways of other countries with which it is reasonable to make a comparison. In the absence of ton-mile statistics no satisfactory comparison can indeed be made under this head; still, it may be not altogether useless to mention that the tonnage carried by the waterways of England and Wales, according to the returns for 1898,[a] was larger than that carried by the waterways of France, Belgium, Germany, or Russia, for the nearest year for which I happen to have the data (in no case more than three years from 1898). England and Wales, moreover, have no waterway like the Ruhr, capable of carrying 165-ton boats and passing through a coal field, yet carrying next to nothing. The 113,000 tons carried in 1898 by the Kennet and Avon Canal and river Avon (railway controlled, be it observed) compares very favorably with the small traffic of the Danube-Main or Ludwig's canal.

The first question, therefore, to ask is, How is it that our poor waterways accomplish so much? and unquestionably the answer is, Because this country has such large quantities of bulky goods originating or collected at some point on a waterway and requiring to be transported to some other point on the same or a connected waterway.

We may next ask how this traffic is divided between the independent and railway-controlled waterways. In making this comparison, I leave out the sea-borne traffic of the Manchester Ship Canal, which is obviously not on the same footing as ordinary inland water traffic, and I omit the Manchester Ship Canal proper in stating the total length of the canals. On this basis we find that the 2,016 miles of independent canals carrried in 1898, in round numbers, 22.5 million tons, the 1,118 miles of railway-controlled canals roughly 13.5 millions. These figures would seem to tell rather in favor of railway control, but, of course, it would be absurd to draw such a conclusion.

[a] Returns in Respect of Canals and Navigations in the United Kingdom for 1898. [Cd. 19], 1899.

Such general comparisons throw no light whatever on the question. It will be more profitable to look at the facts relating to some of the individual navigations.

That which carried by far the greatest amount in that year was the Birmingham Canal Navigation, a miserable narrow-boat system of waterways which wind about and rise and fall in South Staffordshire and the neighboring parts of adjoining counties. But it is their situation that explains their preeminence, the large towns and the mines and quarries of this district supplying and requiring large quantities of bulky produce, such as is indicated in the following table, one column of which is taken from the returns already cited and the second kindly supplied to me by the clerk to the Navigation:

Thousands of tons carried by the Birmingham Canal Navigation.

	1898.	1905.
Coal	4,543	3,786
General merchandise	1,340	1,336
Bricks	846	612
Road materials and manure	655	769
Pig iron	523	434
Ironstone and cinder	478	411
Sand	139	135
Lime and limestone	103	63
Total	8,627	7,546

The "general merchandise," I am informed, is broadly composed of grain, timber, and manufactured goods generally.

The waterway ranking next after the Birmingham Canal Navigation in respect of the volume of its traffic is the Aire and Calder Navigation. Here we have a much better waterway, throughout above 6 feet in depth, with much fewer locks, and, moreover, with large quantities of one bulk commodity (coal) to collect at or near its upper terminals, Leeds and Wakefield, and discharge into ships at its lower end, Goole. This trade has also been greatly promoted by the ingenious contrivances for dealing with this commodity devised by the engineer to the canal, Mr. W. H. Bartholomew, M. Inst. C. E. The coal is carried in so-called compartment boats, really segments of a boat, each carrying 35 tons of coal, and formed into a train which is preceded by an empty segment shaped like the prow of a boat, all drawn by a tug. On the arrival of the train at Goole each compartment is hoisted up in order that its contents may be tipped into the hold of a ship, and on the return of the train the separate compartments are hauled out of the water on rails to be taken to the collieries for refilling.

Time fails us for the examination of other important English waterways, but attention may be drawn to two railway-controlled canals which carry a great deal of traffic, though not with such satisfactory results as the Birmingham Canal Navigation. One of these is the St. Helens, or Sankey Brook, Canal,[a] belonging to the London and Northwestern Railway Company. It is more than 6 feet deep, and runs from the great chemical and glass manufacturing town of St. Helens to the Mersey. In 1898 it carried above 380,000 tons of river sand, chemicals, limestone, sugar, and other produce, but at a loss to the company of £835. It is difficult to conceive what motive the company could have for carrying all this at a loss, if in any way it could contrive to carry it at a profit. The other is a very remarkable and instructive case in more ways than one. It is that of the Swansea Canal,[b] which lies in the valley of the Tawe, and in 16½ miles ascends 333 feet by means of 36 locks. In spite of these adverse circumstances, the canal carried in 1898 192,000 tons at a small profit to the railway company. The explanation is found, however, in the account of it given in the Returns for 1898, where the canal is described as "passing through or alongside the various works—copper, silver nickel, tin plate, and other works, also collieries, quarries, etc." But the instructiveness of this example does not end here. In 1898 the goods stated to have been carried by this canal in order of importance were coal, ores, and pitwood. The manager of the Great Western Railway Company has been good enough to inform me that in 1905 the total tonnage carried by this canal was only 123,000 tons, and that the decrease in traffic was mainly due to the fact that, consequent upon the provision of rail access to a large colliery company's works, that company's output, which formerly passed by the canal, was now all carried by the Midland Railway, and that it was understood that the colliery company had disposed of its water-carrying plant. The coal at present carried by the canal amounts to less than 6,000 tons per annum, and I am assured that, as might be expected, practically the whole of the canal traffic arises at, or is destined for, places in the vicinity of the canal. Now the traffic is carried on at a loss, and in this case it is still more difficult to conceive what inducement the company has to suffer that loss if it can prevent it.

There can be no question, however, that in some cases it must be the interest of the railways to check the development of canal traffic. If the facilitating of traffic on a canal belonging to a railway would tend

[a] This is the canal shown on our map by five large dots to the north of the Mersey.

[b] This canal, inadvertently shown on the map by a continuous instead of a dotted line, is the western of the two canals converging on Swansea.

to divert traffic to other canals instead of the railway, it is in accordance with ordinary business human nature that the railway should be unwilling to grant such facilities, and it is largely on this account that the principal schemes for canal improvement in this country hinge upon the Birmingham Canal Navigation. That, of course, is not the sole reason. The concentration of a mining and industrial population on the area served by that canal affords one of the important conditions favoring through traffic by water to the coast. In the paper already referred to M. Saner has propounded a scheme for connecting this area with the ports of Liverpool, Hull, London, and Bristol by canals capable of being navigated by lighters of 250 tons carrying capacity. But suppose, as Mr. Vernon-Harcourt suggested in his criticism of that scheme, a beginning were made with a project of more modest dimensions, "the actual enlargement of the most promising canal, such, for instance, as the Worcester and Birmingham Canal," let us consider, in the light of what has been set forth, what would be the prospects of traffic on that improved waterway to the sea. The Birmingham area, it may be admitted, is more promising for canal traffic than Berlin. It is rather to be compared with a portion of the area of the Ruhr coal field. Still, the waterway thus provided would be no Rhine. It would not even be equal to the Dortmund-Ems Canal, the disappointing results of which we have already seen. When all the circumstances are considered, the probability is, it seems to me, that nearly all the commodities enumerated above as making up the water traffic of the Black Country would still continue to form merely local traffic. Not improbably there would be some development in the carriage of iron manufactures to Bristol, a development hindered, as compared with the Dortmund-Ems route, by the inferiority of the waterway, but relatively favored through the superiority of the seaports with which Birmingham would be connected. In return there would not improbably be a certain trade in ores, how great it would be difficult to estimate, but so far as it went it would no doubt be a gain to the district. From the experience of Berlin and Germany generally, we may take it as settled that the improved waterway would do little to promote the trade in English agricultural produce. On the other hand, it would help to increase the competition of foreign and colonial produce of that kind with that of home production. Those, therefore, who advocate the spending of public money on canals ought to consider whether this trade, among others, is one that it is desirable to promote by special bounties, such as an unremunerative state-built canal would constitute.

THE PRESENT POSITION OF PALEOZOIC BOTANY.[a]

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Since the general acceptance of the doctrine of evolution, the determination of the course of descent has become the ultimate object of the scientific systematist; the problem is an historical one and the most authentic documents are the remains of the ancient organisms preserved in the rocks. Remote and even unattainable as a full solution of the problem must be, we may confidently hope, in tracing something of the past history of plants, to throw new light on their relationships.

There is probably no branch of botany which has made more rapid advances of late years than the study of fossil plants, and it is especially the investigation of the more ancient floras which is now leading to new results of far-reaching significance. The object of the present article is to give a sketch of our knowledge of Paleozoic plants and their affinities, as affected by recent discoveries.

[a] Abridged and condensed, with the consent of the author, from Progressus Rei Botanicæ, vol. 1, pt. 1, pp. 139–217, 37 figures; Leiden, 1907, Gustav Fischer.

The discoveries among Paleozoic plant fossils have been so rapid during the last decade, and the light thrown on the nature of the ancient extinct types, their mutual relations, and their part in the systematic evolution of the great groups of living plants, has been so important, as well as brilliant, as to excite the interest of students in all branches of botany in all countries. In the partial reformation of Paleozoic botany, and in the task of working out the phylogeny of our lower gymnosperms, in particular, the distinguished author has played the leading rôle among living investigators.

To meet the call for information on the part of American readers this very able, comprehensive, authoritative, and fairly conservative article is printed as fully as space will permit, even including as much as possible of the technical matter, since these widely scattered data have nowhere been assembled in our American literature.

For references to the many papers cited, and for additional illustrations, the reader is referred to the original article and to Mr. Arber's bibliography in the Progressus Rei Botanicæ.

Our subject covers the botany of the whole Paleozoic epoch from the oldest rocks in which plant remains have been found up to the close of the Permian formation. Our knowledge, however, of the different periods embraced within this immense range of time is so unequal that no general description of Paleozoic vegetation can be attempted. In the Silurian, for example, vegetable fossils are so scanty that the data are altogether inadequate to give any idea of the flora of that formation. The Devonian is far richer and of great botanical interest, but its flora urgently needs a critical revision in the light of modern knowledge. It is only when we come to the Carboniferous that the evidence becomes abundant and satisfactory, and it is from this formation that our conception of Paleozoic floras has been essentially derived.

In considering the plant world at such a remote epoch we are prepared to find that the limits and relative development of the various classes were very different from those to which we are accustomed in the recent flora. There is no evidence that the Angiosperms, now the dominant class in the vegetable kingdom, existed in Paleozoic times; on the contrary, their first traces only appear far on in the Mesozoic epoch. Although their history may probably extend much further back than is shown by our present records, there is no reason to suppose that their evolution, as a distinct phylum, had begun in Paleozoic times. On the other hand Gymnosperms, and more primitive seed plants allied to Gymnosperms, were immensely abundant, though belonging, with few exceptions, to families now extinct. The Pteridophyta, while not so predominant as has commonly been supposed, played an important part, and some of their families attained a development far exceeding anything that their recent allies can show. As regards the lower classes of plants, while we have scarcely any knowledge of Paleozoic Bryophyta, there is evidence that Bacteria were present and that Fungi were abundant, though the remains of the latter have not as yet proved of any great botanical interest. The Algæ are somewhat better known, but here also well-characterized specimens are few.

The land vegetation of the Paleozoic period, from the Devonian onward, was in part Pteridophytic and in part Spermophytic. In the light of our present knowledge it appears probable that in the Carboniferous, at all events, the latter element was predominant, and possibly this may already have been the case even in Devonian times. The conception of the Paleozoic age as the reign of the Cryptogams, current from the time of its author Brongniart down to our own day, has lost its validity, owing to the increasing evidence for the seed-bearing character of a large proportion of the forms hitherto classed

as Cryptogamic. The Spermophyta of the Paleozoic period consisted on the one hand of well-characterized Gymnosperms, and on the other of a great assemblage of fern-like forms, resembling the contemporary Gymnosperms as regards their seeds, but separated from them by the primitive character of their general organization; they may be treated as a distinct class—the Pteridospermeæ. In addition to Gymnosperms and Pteridosperms, the ranks of Paleozoic "seed-bearing plants" were further recruited from a different source, the Lycopodiales, some members of which, as recent investigation has shown, had made a great advance in the Spermophytic direction, producing organs closely analogous with true seeds.

The division of vascular plants into Spermophyta and Pteridophyta, though sanctioned by botanical usage, ceases to afford a natural line of cleavage when we are concerned with Paleozoic vegetation. A large proportion of the seed plants of that period were, until recently, classed as Ferns, and though their position has changed there is no doubt that the affinity between the Pteridosperms, as we now call them, and the Ferns was far closer than that between the Ferns and any other known group of Pteridophyta. Further, the Lycopods above referred to, which were reproduced by means of seed-like organs, were in all other respects as true Lycopods as any of their purely Cryptogamic allies.

Hence we have to seek some other line of separation, if we wish, on grounds of convenience, to group the Paleozoic Vasculares under two main divisions.

As a provisional scheme, we may adopt Professor Jeffrey's proposed division of the vascular plants into Lycopsida and Pteropsida, the former including Sphenophyllales (as here limited, a wholly Paleozoic class) Equisetales and Lycopodiales, while the latter embrace the Filicales and the whole of the Flowering Plants.

The characters on which Professor Jeffrey mainly relied as distinguishing his two main groups are three: The Lycopsida are typically microphyllous, the Pteropsida megaphyllous; the Lycopsida are "cladosiphonic," the Pteropsida "phyllosiphonic," i. e., the hollow vascular cylinder (when present) is interrupted in the former only by the exit of branches, forming *ramular* gaps, in the latter by the exit of leaf traces, forming *foliar* gaps; lastly, the Lycopsida are characteristically strobiloid as regards their fructification, while in the Pteropsida strobili, or cones, appear only in the higher members of the division (Phanerogamia). These characters are by no means constant, and are open to much criticism; the general grouping has, however, sufficient claims to be a natural one to afford at any rate a basis for the discussion of affinities.

We may graft on Professor Jeffrey's arrangement a proposal of Professor Lignier's to associate the Sphenophyllales and Equisetales in the subdivision Articulatæ. So far, then, as concerns the groups which we have to consider in this article our provisional classification may take the following form:

Lycopsida	Sphenophyllales.	Articulatæ.
	Equisetales.	
	Psilotales.	
	Lycopodiales.	
Pteropsida	Filicales.	
	Pteridospermeæ.	Spermophyta.
	Gymnospermeæ.	

The Psilotales, though without authentic Paleozoic representatives, are included in the list because it is necessary to discuss their affinities in the light of paleontological data.

The composition of the Vasculares in Paleozoic times was thus widely different from what we find in the recent Flora, not only as to the groups represented but also as to their relative importance. The Pteridophytes and the lower Seed Plants then had the field to themselves, and shared among them all the leading rôles in the vegetable world, filling a place which has since, for the most part, been taken over by families of more modern origin. Groups of plants which now play a subordinate part, or have disappeared altogether, were then richly represented, and in many cases showed a far higher and more varied organization than is found among their nearest allies in later times.

In discussing the affinities of Paleozoic vascular plants there are certain advantages in beginning with the Sphenophyllales, an order which, though not extensive, is important from its synthetic character, and probably represents an extremely ancient stock.

A. Lycopsida.

I. Sphenophyllales.

The extinct order Sphenophyllales ranges from the Middle Devonian to the Permian, or perhaps to the base of the Triassic. It contains but two genera, *Sphenophyllum* and *Cheirostrobus*, each of which represents a distinct family, the genus *Cheirostrobus* being known only by its remarkable cones. The species of *Sphenophyllum* were herbaceous, probably climbing plants, with slender ribbed articulated stems, having a triquetrous solid axis of centripetal primary

wood from the angles of which the leaf traces arise. A secondary or exogenous wood was also developed; in the coal-measure species the tracheides are provided with multiseriate pits. The leaves, borne in verticils at the nodes, are typically cuneate, with dichotomous nerves, but may be divided into numerous linear segments; they are usually six in number and not alternating in the verticils as in the Equisetales. The sporangia are varied in grouping, and are borne on the lobes of more or less modified fertile leaves. (Fig. 1.) The nervate sporangiophores are sometimes peltate, and the sporangia (one to four in number) are usually borne on the ventral lobes, though in one species they are also present on the dorsal. The current statement that they are heterosporous appears to be erroneous.

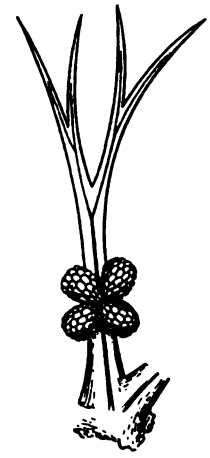

FIG. 1.—*Sphenophyllum majus*. Part of forked sporophyll in surface view, showing a group of four sporangia inserted below a bifurcation. After Kidston.

The *Cheirostrobus* cone, from the Lower Carboniferous, is of great complexity, and is in fact the most elaborate Pteridophytic fructification known to us. A stout axis with a polyarch stele of primary wood containing no pith, bears numerous verticils of highly compound sporophylls. (Fig. 2.) Each sporophyll consists of six segments, of which three are dorsal, sterile, bract-like organs, the remaining three constituting ventral peltate sporangiophores, each of which bears four sporangia.

Intimately related to the Sphenophyllales, if not referable to the same class, is *Pseudobornia*, described by Nathorst from the Arctic Upper Devonian and made the foundation of the order Pseudoborniales. The main stems, which are believed to have been creeping, are of considerable size, reaching about 10 mm. in diameter in their present flattened condition. The stem was articulated and branched, and on the smaller branches the whorled leaves are found in position. Several are borne in a verticil, the number being most probably four; each leaf is of a highly compound form; seated on a short petiole, it divides by repeated dichotomy into several leaflets, which are themselves deeply pinnatified, with numerous fine segments. The fructification is in the form of long, lax spikes, bearing whorled sporophylls, resembling reduced vegetative leaves. A sporangium appears to have been borne on the lower part of the sporophyll, but there is no information as to its mode of insertion. Indications of probable megaspores were observed. Unfortunately the type is at present known only in the form of impressions.

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II. EQUISETALES.

The Paleozoic Equisetales, often made into a class of their own, under the name Calamariales or Calamariaceæ, were one of the dominant groups of plants at that period, attaining the stature of large trees, which appear to have formed an important constituent of the Carboniferous forests. Hence their organization was in various respects on a higher level than that of their recent survivors, represented by the genus *Equisetum;* at the same time, allowing for these

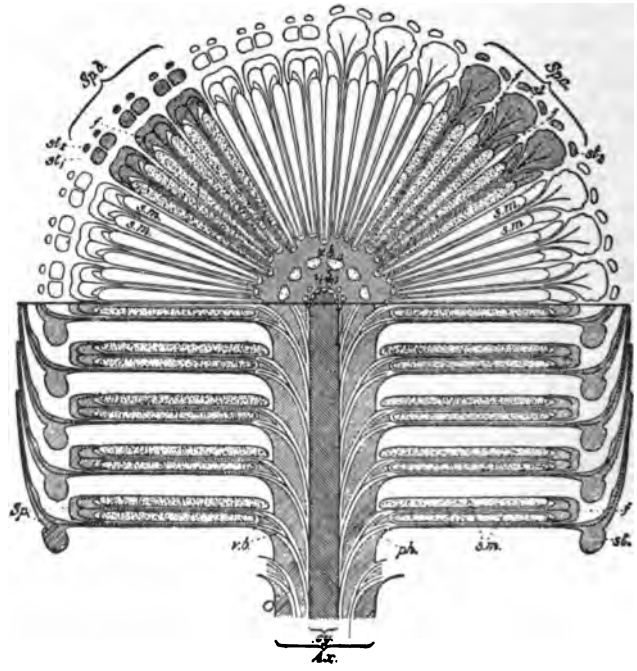


FIG. 2.—*Cheirostrobus Pettycurensis.* Diagram of cone, the upper part in transverse, the lower in radial section. In the transverse section, six sporophylls, each showing three segments, are represented. *Sp. a.*, section in plane of sterile segments; *Sp. b.*, section in plane of sporangiophores; *st*, laminæ of sterile segments; *f*, laminæ of sporangiophores; *sm*, sporangia; *v. b.*, vascular bundles supplying sporophylls; *Ax*, axis; *cy*, stele. The longitudinal section shows the sporangiophores and sterile segments in their relation as ventral and dorsal lobes of the sporophylls; lettering as before.

adaptive differences, the structure of the Calamariaceæ had very much in common with that of our familiar Equisetaceæ.

Even in habit there seems to have been a considerable resemblance to recent forms. The leaves were always in whorls, and usually of simple form and comparatively small size, though not so reduced as in *Equisetum* itself. In the oldest known Calamarian, however, the Devonian and Lower Carboniferous genus *Archæocalamites*, the leaves were often dichotomously compound, thus showing an inter-

esting analogy with the foliage of *Pseudobornia* and the Sphenophyllales. The leafy branches have been divided among the genera *Annularia*, *Asterophyllites* and *Calamocladus*.

The anatomical structure of all parts of the plant is now known in a number of instances, but the correlation of the various organs in their different states of preservation still presents great difficulties.

The anatomy of the stem in its young condition is closely similar to that of a recent *Equisetum* and thus deviates widely from the Sphenophyllaceous type. The usually fistular pith is surrounded by a ring of collateral bundles, each, as a rule, accompanied by its carinal canal, in which the disorganized remains of the spiral tracheides can be detected. Thus the development of the wood was in these cases wholly centrifugal. A certain amount of centripetal xylem is, however, present in one species, *Calamites pettycurensis*, from the Lower Carboniferous of Scotland, lying on the medullary side of the carinal canals. In all except the youngest twigs a zone of secondary wood and bast, often of great thickness, has been formed by means of a normal cambium, the cells of which, together with those of the phloem, can be observed in favorable cases. In *Calamites* itself (the *Arthropitys* of Goeppert) the secondary wood is of a simple structure comparable to that of the less differentiated Coniferous woods, but usually with more or less scalariform pitting on the tracheides. *Calamodendron*, from the Upper, and *Arthrodendron* from the Lower Coal-Measures are characterized by the complex structure of the principal medullary rays, which contain much fibrous tissue in addition to the usual ray-parenchyma. In their vascular anatomy, the Equisetales show a marked advance on the Sphenophyllales; in this respect they reach the level of the simpler Gymnosperms or Dicotyledons—an interesting example of parallel development.

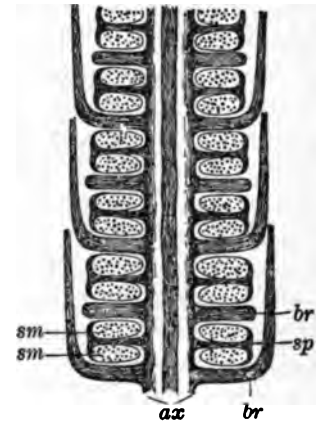


FIG. 3.—*Calamostachys*. Diagram of cone in radial section. *ax*, axis, which bears successive verticils of bracts (*br*) and peltate sporangiophores (*sp*); *sm*, sporangia borne on the sporangiophores. As the bracts are alternate with one another their upturned tips are only shown in every alternate verticil.

The fructifications of the Calamariaceæ are of several different types, nearly all of which show an evident relation to the well-known strobilus of *Equisetum* though usually of more complex organization. They represent several genera described as *Calamostachys* (the most common; see fig. 3), *Palæostachya*, *Cingularia*, *Pothocites*, and *Equisetites*. The cones of these types show considerable variation in the

number and position of the bracts and sporangiophores, some of the latter being apparently in distinct verticils, alternating with those of the bracts. The anatomical characters seem, however, to show an original relation of these sporangiophores as ventral lobes of the bracts. In several of the types spores of two kinds are observed. *Pothocites*, the cone of *Archæocalamites*, has only scattered bracts, while the cone of *Equisetites Hemingwayi* is in its superficial characters distinctly Equisetaceous.

The general morphological agreement between the Equisetales and Sphenophyllales is manifest, as shown by the articulated stems with constant verticillate arrangement of the appendages. *Archæocalamites*, the oldest of the known Equisetales, distinctly approaches the Sphenophyllales in the superposition of the verticils and in the dichotomously divided leaves. In many Calamariaceæ the individual leaves resemble the leaves or leaf-segments of the plurifoliate Sphenophyllums so closely that the external characters scarcely allow of a distinction between the two groups.

These, however, are only outward resemblances. The anatomical study of the mode of origin of the leaf bundles and of the structural changes attending an increase in the number of the leaves affords grounds for believing that the numerous leaves of a Calamite, like those in certain forms of *Sphenophyllum*, represent the segments of a smaller original number. The agreement in the vegetative organs of the two classes appears on the whole sufficiently close to be indicative of real affinity. The difference in the structure of the stele is undoubtedly great, but there are some indications of intermediate forms.

When we come to the fructifications the agreement is more striking. The detailed structure of the sporangia is very similar throughout the two groups, and the resemblance extends to the sporangiophores, which in the case of *Cheirostrobus*, in particular, are practically identical with those of *Calamostachys;* in the bisporangiate Sphenophyllales the agreement is still evident, though it is naturally diminished in the *Sphenophyllum Dawsoni* type, where the sporangiophore has only a single sporangium to carry.

Throughout the Sphenophyllales the sporangiophores appear as ventral lobes of the sporophyll, while in one species the dorsal lobes are also enlisted for the same service. There is anatomical evidence that in *Calamostachys* and *Palæostachya* the sporangiophores are the more or less displaced ventral appendages of the bracts next below them on the axis. The *Equisetum* type of strobilus (already represented in the Paleozoic flora) appears to present difficulties, but they are not insuperable. In *Sphenophyllum fertile* both dorsal and ventral lobes of the sporophyll are fertile, and if the same displacement

took place under these conditions as we actually find in *Calamostachys* there would be a near approach to the *Equisetum* arrangement.

Taking all the characters, vegetative and reproductive, into account, the affinity of the Equisetales with the wholly Paleozoic group Sphenophyllales may be regarded as established. *Archæocalamites*, though it shows some approach to the Sphenophyllales, is none the less a manifest Calamarian, while in *Cheirostrobus* the Sphenophyllaceous characters as evidently predominate. *Pseudobornia* is probably, in the present state of our knowledge, best kept in a distinct class, as Nathorst proposes though perhaps it has the strongest claims of any known genus to be called a Protocalamarian.

III. Psilotales.

It is not my purpose, under the above heading, to discuss the highly doubtful fossils, such as *Psilophyton* and *Gomphostrobus*, which have sometimes been referred to the Psilotaceæ, but rather to consider the affinities of the recent group in the light of our knowledge of the Paleozoic Sphenophyllales. The two points on which the question turns are the anatomy of the stem and the morphology of the sporophyll. As regards the anatomy, *Psilotum* presents a nearer analogy with the Sphenophyllales than any other recent plant, the resemblance being most marked in those branches where the stele is triarch and the xylem extends to the center. The discovery by Boodle that, at the base of the aerial stem and in adjoining parts of the rhizome of *Psilotum*, a well-marked formation of secondary wood may take place in old plants, strengthens the anatomical analogy in a striking manner.

Still closer is the anatomical resemblance in the reproductive organs. For example, in *Tmesipteris* (the less reduced of the two genera of Psilotaceæ) the development and ventral position of the pedicellate synangium and the anatomical relation of the latter to the subtending sporophyll correspond exactly to the conditions in the Sphenophyllales. The repeated dichotomy of the sporophylls, discovered by Professor Thomas, which is so frequent as clearly to fall under the head of normal variations, certainly appear to be fatal to the idea of any near affinity between Psilotales and the Lycopods, while it strongly supports a relationship to the Sphenophyllales rather than to any other group. This relationshp also explains the normally forked sporophyll of *Psilotum* and *Tmesipteris;* it may well represent the dichotomous form of leaf so common in *Sphenophyllum*. There can be no doubt that on the whole of the evidence there is a good case for the Sphenophyllaceous affinities of the Psilotaceæ. The arguments on which the comparison of this group with the Ophioglosseæ have been based apply with far greater force to the Sphenophyllales, and are sup-

ported by additional characters sufficient to indicate real relationship rather than mere analogy.

Professor Thomas considers that we are justified in including the Psilotaceæ in the class Sphenophyllales, and in this he is followed by Professor Bower in his latest works. If we were compelled to choose between Sphenophyllales and Lycopodiales, I should certainly incline to the former alternative, as expressing the nearer affinity, but the differences between Psilotaceæ and the Paleozoic plants which have hitherto constituted the class Sphenophyllales seem to me too great to render a union under the same name desirable. The most obvious difference, of course, is the phyllotaxis, spiral or at least scattered in the Psilotaceæ but verticillate in the Sphenophyllales. From the great constancy of this character throughout the groups included under Articulatæ I am inclined to attach considerable importance to it. Further, on present evidence, the mode of branching seems also to mark a distinction between Psilotaceæ and the Sphenophyllales, dichotomy of the stem occurring in the former, but not, so far as we know, in the latter. For these reasons I prefer to treat *Psilotum* and *Tmesipteris* as forming a class of their own, the Psilotales, having most in common with the Sphenophyllales, though not wholly without the Lycopodiaceous affinities which have hitherto been attributed to them.

IV. Lycopodiales.

As is well known, the Lycopods of the Paleozoic period formed one of the dominant groups of plants, as shown by the great number both of species and individuals, the lofty arboreal habit of most of them, and the high organization which they attained. While the best known representatives, the Lepidodendreæ, were trees, reaching a height of 30 meters or more, there is evidence for the contemporary existence of small herbaceous plants, resembling the Club mosses of the recent flora. The extensive genus *Lepidodendron*, which we may take as typical of the class, ranges from the Devonian to the Permian. The species were trees, with a tall upright shaft bearing numerous dichotomous branches forming a dense crown, and clothed with numerous long and narrow simple leaves, ranged in a complex spiral or verticillate phyllotaxis. When the leaves were shed, their bases remained on the stem, and the sculpturing which they present affords the external characters by which the "species" are commonly distinguished. The markings on the leaf cushion and scar are described in all the text-books and need not detain us here. In habit the Sigillarias must have been peculiar, for the stem appears to have branched but sparingly, or even, in some cases, not at all, the long upright trunk terminating, like a *Xanthorrhœa*, in a sheaf of long, grass-like leaves. The leaves were usually arranged in conspicuous

vertical series, marked, in a large section of the genus, by the presence of prominent ribs.

Anatomically, the stem of the Lepidodendreæ is in all cases monostelic, with centripetal primary wood, which may extend to the center, or form a ring inclosing a medulla. While in *Lepidodendron*, *Bothrodendron*, and some species of *Sigillaria* the primary wood is continuous, in other Sigillariæ (*S. menardi* and *S. spinulosa*) the xylem ring is broken up, more or less completely, into distinct bundles. These bundles, however, never pass out into the leaves, but in all cases the single, usually collateral leaf trace is detached from the stele without giving rise to any leaf gap.

In most species there was a considerable development of centrifugal secondary wood, consisting of tracheides and medullary rays, with a marked radial arrangement of the elements. In a few species (e. g., *Lepidodendron Harcourtii*, the first fossil Lycopod discovered with structure preserved) no secondary wood has yet been observed. Almost without exception both primary and secondary tracheides are of the scalariform type. Although the presence of primary phloem can be recognized with certainty, some doubts have been expressed as to the production of secondary phloem by the cambium. In certain cases (*Lepidophloios fuliginosus* and *Lepidodendron obovatum*) the secondary xylem may be largely, or even wholly, parenchymatous. In all cases, even where secondary vascular tissues have not been observed, there was an extensive formation of periderm, chiefly in the form of a phelloderm probably produced on the inner side of the generative layer.

The leaves show marked xerophytic adaptations; the vascular bundle was surrounded by a sheath of tracheal transfusion tissue, and the stomata were commonly sheltered in two deep grooves on the lower surface of the leaf. In the curious genus or subgenus *Sigillariopsis* the leaf is traversed through most of its length by two vascular bundles, a unique case among Lycopods. According to Renault, the French species of this genus is further remarkable for the occurrence of pitted, as distinguished from Scalariform tracheides.

An interesting feature in the leaves of the Paleozoic Lycopods is the very general presence of a ligule, situated, like that of the recent Ligulatæ, on the upper side of the leaf base and usually seated in a deep pit.

Our knowledge of *Stigmaria*, which represents the subterranean parts of the Lepidodendreæ, is still very imperfect, although fossils of this nature are among the very commonest Carboniferous specimens, both as casts and petrifications. The difficulty is that it is still impossible to refer the various specimens of *Stigmaria* to the species, or even the genus to which they belonged. *Stigmaria* has been found in connection with the stems both of *Sigillaria* and

Lepidodendron. The morphology of *Stigmaria* has been much disputed; so far as the main axis is concerned the best analogy, though a somewhat remote one, appears to be with the rhizophores of Selaginella; the rootlets, which have a totally different structure, agree so nearly with the roots of some recent Lycopods (*Isoëtes* and *Selaginella*) that there seems little doubt as to their homologies, though their peculiar arrangement has led some authors to interpret them as modified leaves.

The Lepidodendreæ are a well-characterized group, as to the affinities of which there can be no doubt, even apart from the evidence of fructification. The primary anatomy is of simple Lycopodiaceous type, comparable to that of the aerial stem of *Selaginella spinosa* or a large stem of *Psilotum*—the higher anatomical organization is chiefly expressed in the general occurrence of secondary growth. Except for the very different arrangement of the foliar traces there is a certain resemblance between the stelar structure of a *Lepidodendron* and that of *Cheirostrobus* among the Sphenophyllales. Otherwise there is little in the vegetative characters which throws any new light on the affinities of the class.

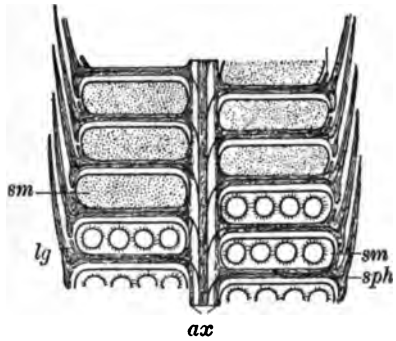


FIG. 4.—*Lepidostrobus*. Diagram of heterosporous cone, in radial section. *ax*, axis; *sph*, sporophylls; *sm*, sporangia, seated singly on the upper surface of each sporophyll; *lg*, ligules. The microsporangia, in upper part of cone, contain numerous microspores, while the megasporangia below are shown containing four megaspores each.

The fructifications of the Lepidodendreæ are grouped under several generic names. In *Lepidostrobus*, the most extensive and oldest established of these genera, the organization is essentially that of a Lycopodiaceous cone. (Fig. 4.) The axis, resembling a vegetative twig in structure, bears numerous spirally arranged sporophylls, each of which has a single large sporangium on its upper surface, attached almost throughout its whole length. The sporophyll has an upturned lamina, between which and the end of the sporangium a ligule is situated, showing that the whole of the long horizontal pedicel on which the sporangium is seated corresponds to the base of the vegetative leaf. The sporangium, often of very large dimensions compared with that of a recent Lycopod, commonly has a palisade-like outer wall. It is almost certain that all *Lepidostrobi* were heterosporous, the microsporangia and megasporangia being sometimes produced on separate cones, sometimes on different parts of the same cone, as in recent *Selaginellæ*. The microspores are very small, while the megaspores are of relatively great size, often

1 or even 2 mm. in diameter. Both are tetrahedral in form. At a point corresponding to the apex of the tetrahedron the megaspore, in most cases, opened by flaps, often highly developed, forming a passage, through which, presumably, fertilization was effected. The prothallus within the megaspore of *Lepidostrobus* is occasionally found preserved, and the archegonia have even been recognized. The cones of *Sigillaria* (*Sigillariostrobus*) also are heterosporous.

In the cones known as *Spencerites* the large sporangium is attached to the bract or sporophyll only at its distal end by a narrow enervate neck. The spores are furnished with a very characteristic wing, which probably aided in dispersal.

The most interesting, however, of the Paleozoic Lycopodineous fructifications are those which show a near approach to the production of seeds. At present two genera are known in which the megasporangium assumed a seed-like character—*Lepidocarpon* and *Miadesmia*. In *Lepidocarpon* the anatomy and morphology of the megasporangiate cone, in its young condition, are in all respects those of an ordinary *Lepidostrobus*. The megasporangia are attached, in the usual manner, to the upper surface of the sporophylls, which are provided with ligules, as in *Lepidostrobus*. The palisade structure of the sporangial wall is also the same as in that genus. In each megasporangium, however, only a single megaspore came to perfection, filling practically the whole cavity, like an embryosac; its three sister cells can often be detected in an abortive condition.

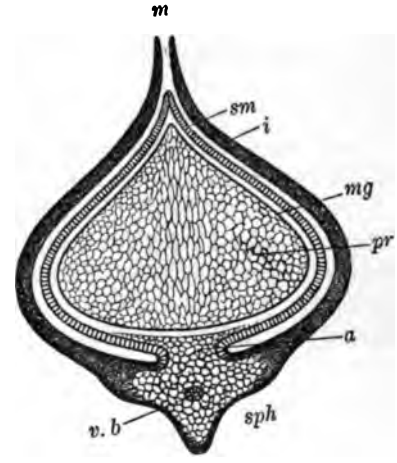


FIG. 5.—*Lepidocarpon Lomaxi*. Diagrammatic section of seed-like organ cut in plane tangential to the parent strobilus. *sph*, sporophyll; *v. b*, vasular bundle; *i*, integument; *m*, micropylar crevice; *sm*, wall of sporangium; *a*, insertion of sporangium on sporophyll; *mg*, membrane of megaspore or embryo-sac; *pr*, prothallus filling megaspore.

At maturity the megasporangium was inclosed in an integument (fig. 5), springing from the upper surface of the sporophyll, and forming a complete investment to the sporangium, except for a narrow crevice along the top, comparable to a micropyle, but of great length, corresponding to the radial elongation of the sporangium. Within the one functional megaspore a prothallus was developed, which is sometimes excellently preserved, and was already present in the earlier stage of the megasporangium before the integument had been formed. The sporophyll, with its integumented megasporangium, was shed entire, and appears to have been indehiscent. The analogies with true seeds,

in the integument, the single megaspore, and the indehiscent character are evident; we are unfortunately without any evidence as to the stage at which fertilization took place. The fossil has long been known, but was formerly confused with the Gymnospermous seed *Cardiocarpon*, with which, of course, it has nothing to do. Microsporangiate cones, probably belonging to *Lepidocarpon*, are indistinguishable from the cones of a small Lepidostrobus, except that there are indications of an incomplete integument around the microsporangium.

In *Miadesmia*, the other genus of quasi-spermophytic Lycopods, the sporophyll bears a ligule exactly like that of the vegetative leaf, and the lamina is fringed in the same way at the margins. The megasporangium is attached, at the proximal end, to the upper surface of the sporophyll, and contains a single megaspore, filling its cavity. Externally the megasporangium is inclosed in an integument, springing from the upper surface of the sporophyll, and leaving only a narrow micropylar opening at the distal end, not at the top as in *Lepidocarpon*. The integument bears long tentacles, directed forward, which may have played some part in guiding the wind-borne microspores to the micropyle.

There is thus a general analogy with *Lepidocarpon*, as regards the essential seed-like features, but the structure is quite different in detail. Of the two the *Miadesmia* fructification is perhaps the more advanced, for the sporangial wall is less developed than in *Lepidocarpon*, an indication that the protective function had been more completely taken over by the integument. Microsporophylls, probably referable to the same plant, have been found. They agree with the megasporophylls as regards the insertion of the sporangium, but no integument is developed.

It is remarkable that seed-like organs should have been found in two genera of Paleozoic Lycopods so different as *Lepidocarpon* and *Miadesmia*, in each of which the character must, no doubt, have arisen independently. We can only conjecture that the circumstances of the time may have been peculiarly favorable to the adoption of the seed habit. The early development of the prothallus, in the case of *Lepidocarpon*, makes it very probable that pollination, if not fertilization, took place on the parent plant, but we have no direct evidence on the subject. One striking difference from a typical seed is the fact that in both genera the whole sporophyll was shed with the megasporangium, and formed part of its investment. Analogies with the achenes and nuts of Angiosperms are too remote to be of service, and we must admit that in these Paleozoic Lycopods the participation of the sporophyll marks a low grade of seed evolution. In fact it is evident that in every respect the seed-like organs in question, even if they were functionally seeds, still stand very near the Cryptogamic

type. In this they differ strikingly from the seeds of the Pteropsida series, which even in the earliest known examples are already highly differentiated organs, with little trace of their Cryptogamic origin.

Though there appears to be no sufficient evidence of any relation between the "seed-bearing" Lycopods and the higher plants, these curious fructifications are of great interest, for it is only in *Lepidocarpon* and *Miadesmia*, and, in a different way, in certain species of *Selaginella* at the present day, that we are able, as it were, to observe a seed *in statu nascendi.*

As regards the relation of Paleozoic to recent Lycopods, it seems most probable that the latter were derived, for the most part, from forms (perhaps such as *Lycopodites*) which have always been herbaceous, rather than that they are the reduced descendents of arborescent Lepidodendreæ. It is possible, however, that the Triassic genus *Pleuromeia* may represent a link between the latter group and the recent *Isoëtes*, which, of all the living Lycopods, appears to have most in common with the Lepidodendreæ.

THE SYSTEMATIC POSITION OF LYCOPSIDA.

We have now to consider whether the classes grouped together in the Lycopsida really form a natural association, more nearly related among themselves than to outlying families of plants. So far as the Sphenophyllales and Equisetales are concerned, the affinities are clear and undoubted. We have also found reason to believe that, in a different direction, the Sphenophyllales show an affinity with the recent Psilotales. It is unfortunate that we have as yet no certain knowledge of the geological history of the Psilotales themselves; it is not to be supposed that they sprang from the Sphenophyllales as actually known to us, but rather that the two groups had a common origin. The same remark applies to the Equisetales, which, though nearer to the Sphenophyllaceous type, can not have been derived from any of the specialized forms of which alone the remains have come down to us. The Sphenophyllales as represented in the Carboniferous Flora are best regarded as the last, highly modified, members of an ancient synthetic stock which in still earlier times appears to have had genetic relations to various other Pteridophytic phyla. The Devonian *Pseudobornia*, though at present placed in a class of its own, may well have belonged to the same main stock with the Sphenophyllales.

The most difficult question is that of the relation of the Lycopodiales to this phylum. Anatomically an affinity seems indicated, for the simpler protostelic Lycopods agree very nearly with the Sphenophyllaceous type of stem structure as represented in *Cheirostrobus*. The verticillate arrangement of the appendages and their vascular strands scarcely causes any difficulty, for it frequently

occurs among Lycopods, though probably not in the form of superposed whorls. In the prevailing simple structure, both of the leaf and of the reproductive apparatus, the Lycopodiales differ widely from the Sphenophyllales. In these characters as well as in other respects the Lycopods constitute a wonderfully homogeneous group, so neatly rounded off as to give little hold for any hypothetical link with other classes of plants. *Sigillariopsis*, with its double foliar bundle, departs in some degree from the typical simplicity of structure, but there is not the slightest reason for regarding this peculiarity as an ancestral character.

In certain respects the Psilotales tend to connect Sphenophyllales with Lycopods, for while anatomy and morphology alike indicate a nearer affinity with the former, some relation to the latter may no doubt be traced in the anatomy and habit. In spite of this, the Lycopodiales remain a very isolated class, and though some connection with the ancient phylum represented by the Sphenophyllales appears probable, the common stock must lie very far back. Whether the simple relation between sporangium and sporophyll which characterizes the Lycopod series is native or acquired, may be left an open question. The analogy of the Psilotales rather suggests the latter alternative, and all comparative morphology teaches how often progress consists in simplification.

On the other hand, while not agreeing with Professor Lignier as to the isolation of the Sphenophyllales from the Psilotales and their close affinity with the Filicales, I admit that a relation between the Sphenophyllales and primitive Filicineæ may be conceded as probable. Though the main divisions Lycopsida and Pteropsida have been adopted here as convenient associations, I am inclined to extend the synthetic view of the Sphenophyllales so far as to admit that they retained some characters, such as the venation of the leaves, common to the Filicinean phylum.

B. Pteropsida.

V. Filicales.

There is no part of fossil botany in which there have been such revolutionary changes within a very short period as in the question of the position of Paleozoic Ferns. Till within the last three years the Ferns were universally regarded as forming one of the dominant classes of Paleozoic plants—in fact, the most dominant of all—and this estimate of their importance will be found in all the text-books. According to the computations of systematists the Ferns constituted almost exactly one-half of the known Carboniferous flora. The position has now so completely changed that Professor Zeiller, than whom there is no higher authority, wrote, in August, 1905, that the

Ferns of the Paleozoic period, though "they were probably not entirely absent, occupied an altogether subordinate rank."

The ground for the radical change of view which Professor Zeiller's words indicate is, of course, to be found in the recognition of the Pteridosperms, a class of seed-bearing plants, to which, as it now appears, the great majority of the supposed Paleozoic Ferns belonged. Professor Zeiller further points out that the reduction in the number of true Ferns becomes more marked the earlier the period to which we go back; the Westphalian Flora is already less rich in true Ferns than the Stephanian, and one may almost raise the question whether, in the epochs of the Culm and the Devonian, Ferns really existed. Mr. Kidston, writing a few months later, finds no evidence of "true Ferns" below the Middle Coal Measures, and comes to the conclusion that the Cycadofilices (Pteridosperms) "long antedated the advent of true Ferns." It may be pointed out, however, that under the name "true Ferns" Mr. Kidston does not include the Botryopterideæ, which, as he himself recognizes, are certainly represented in Lower Carboniferous rocks. This family, in fact, has come to occupy an important position, for in the present state of our knowledge it represents the best-attested group of Paleozoic Ferns. Almost all the well-known and striking genera of Fern-like fronds have now come under suspicion, and cannot be accepted as affording in themselves any evidence for the existence of Ferns, as distingushed from Fern-like Spermophyta. The presence of seeds has been actually demonstrated in members of the genera *Sphenopteris*, *Neuropteris*, *Ancimites*, and *Pecopteris;* the evidence is almost equally convincing in the case of *Alethopteris;* in numerous other genera, such as *Eremopteris*, *Odontopteris*, *Linopteris*, and *Lonchopteris*, all the indications are in favor of seeds having been borne, though at present there may not be much beyond association to guide us. It is highly probable that some of these form genera are purely artificial associations, which include Ferns as well as Fern-like seed plants; in *Pecopteris* especially, while one species, *P. Pluckeneti*, undoubtedly bore seeds, as Grand 'Eury has shown, many others show the well-known fructifications commonly regarded as those of Marattiaceous Ferns. Even in the latter cases, however, the question is not free from difficulty, for recent work has proved that some of the supposed Marattiaceous fructifications were in reality the microsporangia of Pteridosperms.

PRIMOFILICES.

The family Botryopterideæ on present evidence appears to have been representative of a comparatively simple type of Filicineæ, of great antiquity. Whether we call them "true Ferns" or not is immaterial; they certainly do not belong to any of the existing families, though they show relations to them in various directions.

In the genus *Botryopteris*, type of the Botryopterideæ, the stem (probably a rhizome) has a remarkably simple structure, the stele consisting of a solid strand of tracheides surrounded by phloem. The relatively large petioles, borne in a spiral order on the stem, contain a single bundle, with a characteristic ω-like transverse section. The stem also bore numerous diarch adventitious roots, an indication of its rhizome nature.

In all respects the characters of the vegetative organs were those of a simple type of Fern, comparable, as Renault at once recognized, to the recent Hymenophyllaceæ. The fructifications confirm the Filicinean affinities of the genus, but at the same time show it to be very different from any Fern now living. The sporangia, densely grouped in tufts on the naked rachis of a modified frond, are of large size (1.5–2 mm. in length) and are characterized by the broad annulus, forming a longitudinal band many cells in width, running the whole length of the sporangium on one side. No very close analogy for this structure is to be found among recent Ferns, though the areola of the Osmundaceous sporangium may be regarded as a shortened multiseriate annulus. In *Zygopteris* we have a much more advanced type. The stele has in some species a stellate contour, the prominences corresponding to the insertion of the leaf traces; the wood is of complex structure, the larger elements forming a broad external zone, while the interior is occupied by a system of smaller tracheides intermingled with parenchyma. In this respect there is a striking agreement with the structure of some Hymenophyllaceæ (e. g., *Trichomanes radicans* and *T. reniforme*), an agreement which is much emphasized by the fact that in several species of *Zygopteris* the branching was axillary, exactly as in the recent family. In *Zygopteris corrugata*, however, the branching was more of the nature of a dichotomy. The well-known double-anchor form of the petiolar bundle is characteristic of the genus. It is rare to find any traces of the lamina in petrified specimens, but a large bipinnate frond with flabelliform leaflets has been referred on good grounds, to the genus, under the name of *Zygopteris pinnata*. The sporangia (fig. 6) are borne on a special fertile frond; they are characterized by the fact that the broad, multiseriate annulus is present on both sides of the pyriform sporangium.

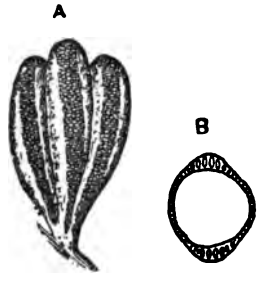


FIG. 6.—*Zygopteris pinnata*. A, Group of sporangia in surface view. × 10. B, Sporangium in transverse section, enlarged. After Renault.

The genus *Corynepteris* includes fronds of Sphenopteroid habit bearing sporangia grouped in circular sori, recalling the synangia of

certain Marattiaceæ; but each sporangium has a multiseriate annulus closely resembling that of *Zygopteris*.

Other genera which on the characters of stem structure may be referred to the Botryopterideæ are *Anachoropteris*, *Asterochlæna*, and *Tubicaulis*. The earliest of these (*Asterochlæna*) dates from the Upper Devonian.

The new genus, *Botrychioxylon*, has the elements of its outer zone radially arranged, constituting, to all appearance, a secondary tissue, just as is the case in *Botrychium* among recent Ferns. Anatomically *Botrychioxylon* shows a relation to *Zygopteris*, like that of *Botrychium* to *Ophioglossum*. On the characters of the sporophylls and sporangia the nearest comparison of *Botrychioxylon* appears to lie with the Osmundaceæ and Ophioglossaceæ, while the anatomy and mode of branching of *Zygopteris* shows the closest analogies with the Hymenophyllaceæ. The group has been considered as a synthetic

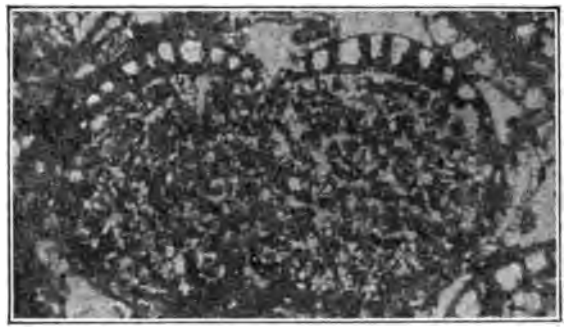


FIG. 7.—*Pteridotheca Williamsoni*. Two sporangia, to show the annull. From a photograph by Mr. Boodle. × about 70.

one, not improbably representing the stock from which some at least of the families of recent Ferns were derived. Mr. Arber regards the Botryopterideæ as but one important family of the ancient race of Ferns to which he gives the general name of Primofilices, and considers it more than probable that this race gave rise to the Leptosporangiatæ. The relation of the Botryopterideæ, or rather of the Primofilices in general, to the Pteridosperms is an important question to which we shall return below.

Other types which we may safely assign provisionally to the group Primofilices include *Stauropteris* and certain petrified sporangia which possess an annulus or other characters indicating Filicinean affinity, and which I have therefore designated *Pteridotheca*. The sporangia of *Pteridotheca Williamsoni* are borne in sori on the incurved margins of a much-divided leaf, apparently of Sphenopteroid form. They are sessile, with a multicellular base, and ellipsoidal or nearly spherical in form, though their sides are often flattened by

mutual pressure. The wall, as preserved, is usually one cell thick and is provided with a conspicuous annulus, extending partly round the sporangium, and, when cut lengthways, strongly recalling the familiar Polypodiaceous annulus. (Fig. 7.) Transverse sections, however, show that the annulus is really two cells in width. The spores, often well preserved, are numerous, and of one kind only, so far as observed. No clear case of a uniseriate annulus in Fern sporangia of Paleozoic age has yet been demonstrated.

The fortunate discovery of the germination of spores, with the development of a prothallus and rhizoids within the sporangium of *Stauropteris Oldhamia*, is good evidence that the latter, at any rate, was a true Fern. Another similar though larger sporangium containing germinating spores is probably also referable to *Stauropteris*.

The probability is in favor of an affinity between the genus *Stauropteris* and the Botryopterideæ, though the sporangial characters scarcely admit of a definite reference to that family. The discovery of the germinating spores just mentioned much strengthens the conclusion that the Botryopterideæ and allied Paleozoic plants were really members of an ancient race of Ferns.

PALEOZOIC MARATTIACEÆ.

No conclusion in Paleobotany has met with more general acceptance than that of the prevalence of Marattiaceous Ferns in the Carboniferous Flora. The evidence is well known, and needs only the briefest recapitulation here. A number of fructifications, such as *Ptychocarpus*, *Scolecopteris*, *Asterotheca*, *Hawlea*, etc. (see fig. 8), agreeing closely with the synangia of recent Marattiaceæ, have been found *in situ* on fronds of the *Pecopteris* type. In some cases the minute structure of the fructifications can be studied in petrified specimens, and entirely confirms the inference drawn from external characters. It would be difficult, in fact, to find clearer evidence of affinity between a recent and a fossil group of plants than is afforded by these synangia. But this is not all. A number of petrified stems, constituting the genus *Psaronius*, are known, in which the anatomy has been fully investigated, and proves to agree more nearly with the structure of Marattiaceæ than with that of any other group of plants. The anatomical agreement holds good in spite of a considerable difference in habit, the fossil stems (known as *Caulopteris*, *Megaphyton*, etc., when preserved as casts) having attained arboreal stature. Recent investigation by Rudolf, of the structure of the Psaronii, with special reference to their relation to Marattiaceæ, further confirms their affinity. From the evidence of comparative structure and association it appears certain that the *Psaronius* stems bore the foliage of *Pecopteris*, of the same nature as the leaves on which the

various synangic fructifications above mentioned have been found. Thus we have to do with a group of plants showing affinity with Marattiaceæ, alike in their anatomical structure and in the characters of their reproductive organs. The conclusion appears to be unassailable, and yet in view of Mr. Kidston's discovery that a typical *Crossotheca* was born on the fronds of *Sphenopteris Höninghausii*, showing this fructification, which would previously have been classed as Marattiaceous, to have constituted the pollen-bearing apparatus of a Spermophyte, and of the fact that the Crossothecas, as a group, involving several species of *Pecopteris*, will no doubt prove to have been of the same nature, we can not, in the present state of our knowledge, feel sure where the encroachments of the Pteridosperms will stop. Considering the anatomical evidence, however, it seems impossible to doubt that Paleozoic Marattiaceæ actually existed, for the *Psaronius* type of stem is altogether Fern-like in structure and presents none of those anatomical features by which the Cycadofilices were recognized, long before the evidence of fructification led to the foundation of the class Pteridospermeæ.

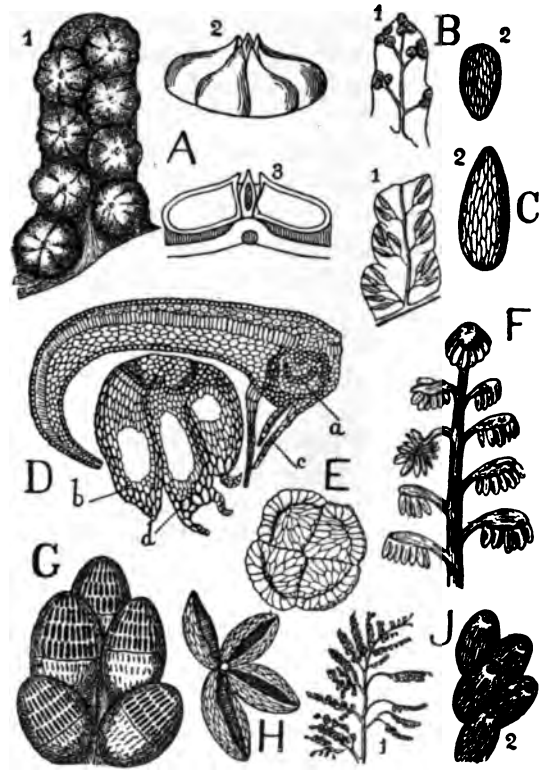


FIG. 8.—Group of Fructifications of Ferns or Pteridosperms. A, 1, 2, 3, *Asterotheca* (Marattiaceous?). B, 1, 2, *Renaultia* (affinities doubtful). C, 1, 2, *Dactylotheca* (doubtful). D, *Sturiella*, in section; *a*, bundle; *b*, *d*, annulus; *c*, hairs (cf. *Corynepteris*). E, *Oligocarpia* (cf. Gleicheniaceæ. F, *Crossotheca* (♂ fructification of Lyginodendreæ). G, *Senftenbergia* (cf. Schizaeaceæ). H. *Hawlea* (Marattiaceous?). J, 1, 2, *Urnatopteris* (affinities doubtful). After various authors.

For the present, therefore, we must continue to accept the existence of a certain number of Marattiaceous Ferns, especially in the later Carboniferous and Permian periods, though we may not always be able to distinguish their fructifications from the pollen-bearing organs

of Fern-like seed plants. Whether this surprising similarity is merely a case of "parallelism of development," as Mr. Arber suggests, or is indicative of affinity, must be left an open question. A direct affinity seems improbable, but it must be remembered that in *Corynepteris* we appear to have the sporangia of Botryopterideæ grouped in synangia like those of Marattiaceæ, and it is possible that in *Sturiella* (fig. 8, D) we may have another case of the same kind. It is therefore a not improbable conjecture that Marattiaceæ and Pteridospermeæ may owe their synangic fructifications to common descent from a primitive group of Filicales in which the character had already appeared.

From what has been said above, it will be evident that our knowledge of Paleozoic Ferns is now in a transitional and somewhat unsatisfactory condition. The old ideas of their predominance have gone, never, probably, to return. There is no longer any presumption that a Fern-like frond really belonged to a Fern; even where some of the reproductive characters seem to point the same way, the inference, as we see in the case of *Crossotheca*, may be quite fallacious. We now have to seek laboriously for evidence, which formerly seemed to lie open to us on all hands. I believe, however, that such careful investigation will result in the resuscitation of the Paleozoic Ferns as a considerable, though not as a dominant group. The petrified material, on which we now have chiefly to rely, indicates the presence of true Ferns,[a] not only in the Upper but in the Lower Carboniferous, and if this is so there is no reason to doubt that they extended back as far as any Vascular Plants. Eventually we may hope to be able to recognize them in the form of impressions, though now it is only in rare cases that we can distinguish such specimens with certainty from the foliage of Fern-like Spermophyta.

At present our knowledge of the Paleozoic Ferns centers in the group Botryopterideæ, the type-family of that ancient Filicinean stock, which has now come to be of supreme interest in the geological history of Vascular Plants.

VI. Pteridospermeæ.

In reviewing the attenuated ranks of the Paleozoic Ferns, it has often been necessary to refer to the contemporary Fern-like Spermophyta which have so largely displaced them. We have now to consider, as briefly as may be, the evidence we possess as to the nature and extent of the Pteridospermeæ and the justification of their existence as a distinct class of plants. I do not propose to trace historically

[a] I use this phrase, not in the limited sense in which Mr. Kidston employs it, but to include all Cryptogamic Filicales as distinguished from Fern-like seed plants.

the growth of our knowledge, but rather to attempt a concise statement of the present position of the question. I will begin with the Lyginodendreæ, the type member of which, *Lyginodendron Oldhamium*, has now been investigated in all its parts.

LYGINODENDREÆ.

The stem of *Lyginodendron Oldhamium* presents a structure in which, at first sight, Cycadean characters appear to predominate. (Pl. I.) There is a pith of considerable size surrounded by a zone of wood and bast, with a layer of cambium, sometimes perfectly preserved, between the two; the greater part of both wood and phloem shows a regular radial seriation of the elements, and is clearly of secondary origin, the structure resembling that of the corresponding tissues in a recent Cycad. Around the pith, however, several distinct strands of primary wood are evident, a character not met with in the vegetative stem of Cycads.

The primary xylem-strands belong to the leaf-trace system of the plant; they pass out through the zone of secondary wood into the pericycle, which they traverse for some distance, here, of course, assuming the character of complete collateral bundles. During its passage through the pericycle each leaf trace divides into two. The leaf-trace bundles of *Lyginodendron* have precisely the structure of the foliar bundles of recent Cycads, for their xylem is of the mesarch type, the centripetal portion exceeding the centrifugal in amount. The occurrence of this structure in the stem of *Lyginodendron* suggested a search for mesarch bundles in axial organs of Cycadaceæ, and they were found to occur in the peduncles of the cones of *Stangeria* and some other genera. It may be pointed out that the tracheides of *Lyginodendron*, like those of almost all Pteridosperms investigated, are characterized by multiseriate bordered pits. On pl. I is shown the general structure of the stem, which need not be described in further detail.

In its usual mature condition the structure is thus, on the whole, of a Cycadean type; in the fortunate cases, however, where a young stem, before secondary growth had begun, has come under observation, the resemblance to the stem of an Osmundaceous Fern is very striking.

When we come to the foliage we find that Fern characters altogether predominate. The petioles have often been found in connection with the stem, on which they are usually arranged in a 2/5 phyllotaxis. The foliar bundles, on entering the petiole, become more or less fused, and assume a concentric structure, which they maintain throughout the rachis, becoming collateral again in the leaflets. The highly compound foliage has long been recognized as

identical with that of *Sphenopteris Höninghausii*, a fact which Mr. Kidston has recently demonstrated by a detailed comparison. The main rachis forked at some little distance from the base, a character which is shown in structural specimens as well as in impressions.

The branching of the stem appears to have been axillary. The adventitious roots, commonly found in connection with the stem, had when young a somewhat Marattiaceous character, but on undergoing secondary growth assumed the structure of the roots of Gymnosperms.

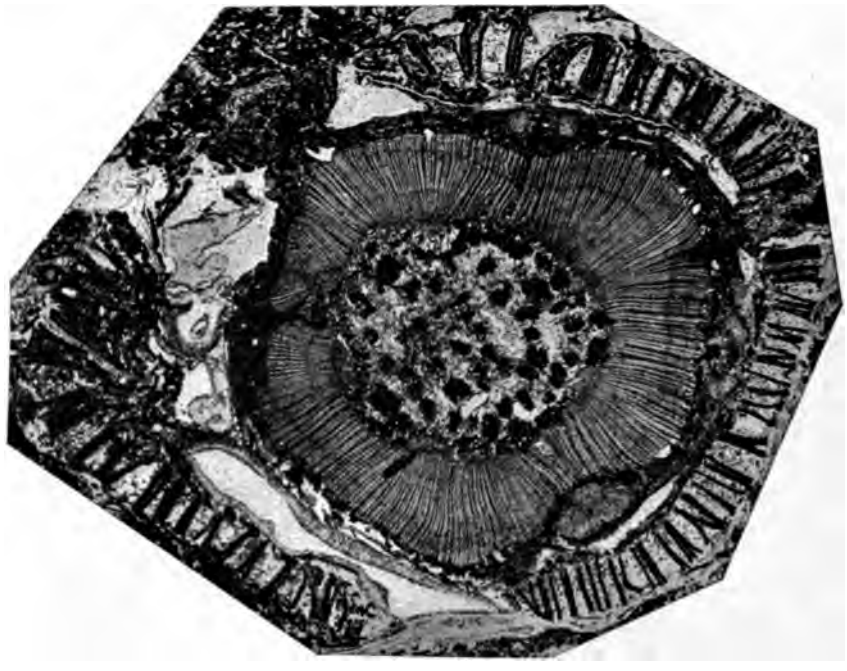
Thus the vegetative organs of the plant present a manifest combination of Filicean and Gymnospermous characters indicating affinities in both directions. The convenient name Cycadofilices, introduced by Potonié in 1897 for plants in this intermediate position, has been generally adopted. Both the stem and leaves of *Lyginodendron Oldhamium* are studded with multicellular outgrowths, like blunt spines, which in certain cases assume the character of capitate multicellular glands. These glands enabled Professor Oliver first to identify the seed of *Lyginodendron*.

FIG. 9.—Restoration of the seed of *Lyginodendron*, from a model by Mr. H. E. Smedley. The seed is surrounded by the open cupule, studded with capitate glands.

The seed, *Lagenostoma Lomaxi* (pl. 1), is inclosed in an outer envelope or cupule, which bears numerous capitate glands identical in structure and form with those on the vegetative organs of *Lyginodendron Oldhamium*. The vascular bundle of the pedicel has the same structure as that of a small rachis of *Lyginodendron*, while the smaller bundles which traverse the cupule agree with those in the lamina of the vegetative leaflets.

The cupule of the seed *Lyginodendron* was a deeply lobed envelope which we have compared to the husk of a hazel nut. (See pl. 1 and fig. 9.) It overtopped the seed, and inclosed it in the young condition. The pedicel bearing the seed is traversed by a concentric vascular bundle, which, before entering the chalaza, gives off numerous branches into the cupule.

The seed itself is orthotropous and generally of Cycadean organization; it shows complete radial symmetry. It possesses a single integument, adherent to the nucellus except in the apical region. The single chalazal bundle breaks up into about nine strands, which trav-



LYGINODENDRON OLDHAMIUM. TRANSVERSE SECTION OF STEM, SHOWING PITH, PRIMARY XYLEM-GROUPS, SECONDARY XYLEM, PHLOEM, PERICYCLE, AND CORTEX. × ABOUT 2½.

The leaf-trace bundles are seen outside the wood.

LAGENOSTOMA LOMAXI, THE SEED OF LYGINODENDRON OLDHAMIUM, IN LONGITUDINAL SECTION, INCLOSED IN THE LOOSE CUPULE, BEARING CAPITATE GLANDS. × ABOUT 15.

erse the inner layers of the integument. The upper free part of the latter has a complex chambered structure; there are usually nine chambers, each of which receives one of the integumental bundles. The outer layer of the integument has a columnar structure. The free apex of the nucellus is prolonged upward through the micropyle, protruding somewhat beyond it, as an open tube. (Fig. 10.) As in recent *Cycads* and in *Ginkgo*, the apex of the nucellus contains the pollen chamber, which here has a peculiar form, for the middle of the chamber is occupied by a solid column of tissue, reducing the actual cavity to an annular channel in which the pollen grains are found. (See pl. 1 and fig. 10.) Within the body of the nucellus is the membrane of the megaspore or embryo sac. The seed was thus of com-

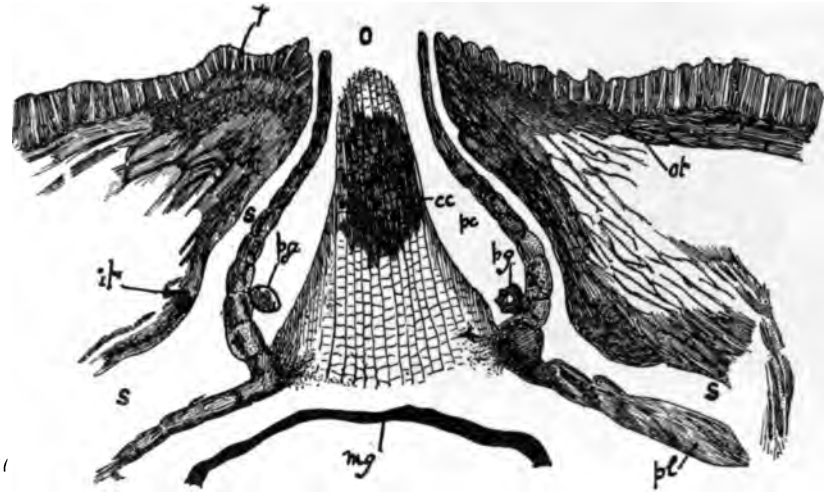


FIG. 10.—*Lagenostoma Lomaxi.* Apex of seed in median longitudinal section through micropyle. *ot,* outer part of testa; *r,* palisade layer; *it,* inner part of testa; *s,* cavity between testa and nucellus; *o,* orifice of pollen-chamber, *pc; cc,* central column; *pg,* pollen-grains; *pl,* nucellus; *mg,* megaspore. × about 50. After Oliver.

plex organization and shows that *Lyginodendron*, in spite of its surviving Fern-like characters, had definitely attained the rank of a typical Spermophyte.

The structure of the pedicel indicates that the seed was borne on a foliar organ. The evidence of other species leaves no doubt that the sporophylls were modified fronds or pinnæ of compound form, chiefly differing from the sterile foliage in the suppression of the laminæ of the leaflets.

The stellate lobed indusia or cupules belonging to *Calymmatotheca Strangeri*, a species closely allied to *Sphenopteris Höninghausii*, is shown in fig. 11, drawn from Stur's original specimen. Another related type, *Lagenostoma Sinclairi* (fig. 12), representing both seeds and cupule, has been described by Arber.

Lastly, M. Grand'Eury has observed six-lobed cupules, in some cases still containing the seeds, situated at the extremity of long, slender pedicels, identical with the ultimate ramifications of the rachis of the associated *Sphenopteris Dubuissonis*, another ally of *Lyginodendron*.

The pinnules bearing the male organs of *Lyginodendron* occur on the same fronds which bear the ordinary vegetative leaflets, so that Mr. Kidston was able to demonstrate direct organic connection with

FIG. 11.—*Calymmatotheca Stangeri*. Rachis of the fertile frond, bearing numerous deeply lobed cupules. Drawn by Miss Woodward from Stur's original specimen.

the foliage of *Lyginodendron Oldhamium*. The fertile lobes are pedicellate, oval in form, and each of them bears from 6 to 8 lanceolate, sharply-pointed microsporangia, described by the author as bilocular. When young the microsporangia are bent inward, with their apices meeting at the center, but at maturity they spread outward, appearing like a fringe hanging from the margin of the pinnule, though in reality attached to its lower surface. In all respects the fructification agrees with *Crossotheca* (see fig. 8, F) and it is named *Crossotheca Höninghausii* by Mr. Kidston. Though the speci-

mens are not in the petrified condition, it was found possible to isolate the microspores, which are still contained in the sporangia.

It is a point of great interest that the male fructification of *Lyginodendron* should have been borne on the same frond which elsewhere shows the usual vegetative characters. In this respect *Lyginodendron* was at a lower stage of differentiation than many Ferns, and far below the level of any seed plants previously known.

About a year before Mr. Kidston's discovery, Miss M. Benson had described a synangic fructification, with structure preserved, which she named *Telangium Scotti*, and was inclined to refer to *Lyginodendron*. In this fructification, from 4 to 8 mm. long, pointed sporangia are partially united to form synangia, much like some of those attributed to Marattiaceæ. The best evidence for reference to *Lyginodendron* was afforded by the spores, which agree very nearly with

a *b*

FIG. 12.—*Lagenostoma Sinclairi*. *a*, Portion of branched rachis bearing cupulate seeds. natural size. *b*, Two seeds inclosed in cupules and borne on branches of the rachis. × 3½. After Arber.

the pollen grains found within the pollen chamber of species of *Lagenostoma*. From observations of my own I think it probable that Miss Benson's *Telangium* may turn out to have been a *Crossotheca* and that the bilocular sporangia observed by Mr. Kidston may be an indication of synangic structure.

In any case it appears that the reproductive organs of *Lyginodendron* present the same combination of characters which is shown so clearly in the vegetative structure. While the highly organized seed strongly indicates Cycadean affinities, the microsporangiate fructification is entirely Fern-like in its nature.

Before leaving the Lyginodendreæ, it may be pointed out that *Heterangium* (with the foliage of *Sphenopteris elegans* and other species), though its fructification is not yet known, is clearly shown by its anatomical structure to belong to the same family with *Lygino-*

dendron. Anatomically it stands at a lower level than that genus, for its vascular cylinder is without a pith, constituting a protostele analogous to that occurring in most species of the recent Fern-genus *Gleichenia*.

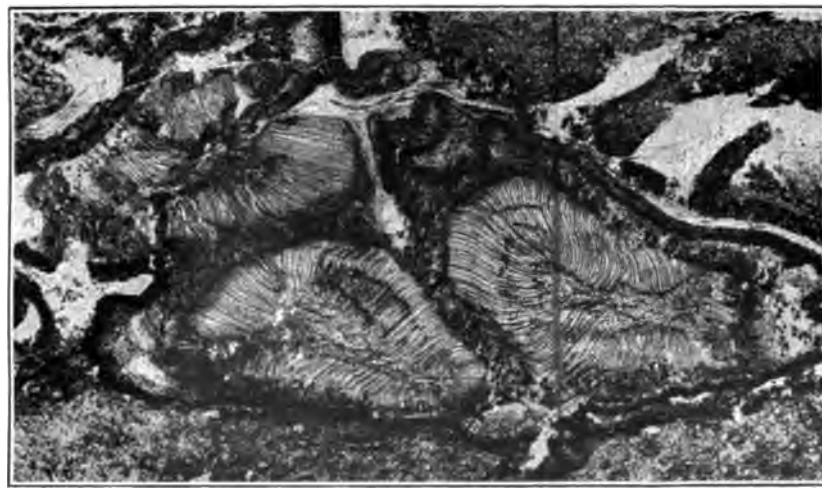
NEUROPTERIDEÆ.

In the well-known species *Neuropteris heterophylla* (pl. II), bodies of about the size and shape of a small hazelnut were found by Mr. Kidston, in material from the Middle Coal Measures, attached to a rachis bearing the characteristic pinnules (fig. 13). Unfortunately there is no preservation of structure in this case, but the external characters afford sufficient evidence of the seed nature of the organ. Beyond the fact that the seed was one of those with radial symmetry and that it had a fibrous envelope, there are no details to record. The point of chief interest is the fact that these large seeds were borne on a frond so little modified as to show the ordinary vegetative form of pinnule, another indication of the absence, in this group, of differentiated sporophylls. According to Mr. Kidston, the seeds fall under the genus *Rhabdocarpus* of Göppert and Berger.

FIG. 13.—*Neuropteris heterophylla*. Seed, attached to a branch of the rachis bearing two characteristic pinnules. × 2. After Kidston.

Mr. Kidston was thus the first to observe direct continuity between the seed and the frond in a Fern-like Paleozoic plant. The family of the Neuropterideæ, of which the plant in question is a representative, is well known from a structural point of view. As Renault demonstrated in 1883, the petrified petioles named *Myeloxylon* by Brongniart belonged to the fronds of *Neuropteris* and *Alethopteris*, while Weber showed that *Myeloxylon* petioles were borne on *Medullosa* stems. Thus we have a fairly complete knowledge of the anatomy in certain members of the family. The stems of *Medullosa*, as has long been known, have a complex structure, the vascular system being of the "polystelic" type, with secondary formation of wood and bast around each stele. This structure finds its simplest expression in the British species *Medullosa anglica* of Lower Coal-

NEUROPTERIS HETEROPHYLLA. PART OF VEGETATIVE FROND, SLIGHTLY ENLARGED.



MEDULLOSA ANGLICA. CENTRAL PART OF STEM, SHOWING THE THREE STELES WITH THEIR PRIMARY AND SECONDARY WOOD. × ABOUT 3.

Measure age. (See pl. II.) The leaf bases, with typical *Myeloxylon* structure, are attached to the stem. The steles are three in number, each with a solid axis of primary wood, surrounded by secondary wood and phloem. (Pl. II.) The leaf-trace bundles, given off from the outer surface of the steles, are concentric in the lower part of their course, but soon break up into a number of collateral strands, with external protoxylem. A large number of these collateral bundles enter the petioles, which thus have a very Cycadean type of structure, chiefly differing from those of recent Cycads in the fact that the wood of the bundles is, as a rule, wholly centripetal, while in the living family the foliar bundles are mesarch. The triarch adventitious roots, which spring from the stem between the leaf bases, also bear a considerable resemblance to those of Cycads.

The leaf of *Medullosa anglica*, as shown by the characters of the rachis and leaflets in the petrified specimens, was that of an *Alethopteris*, probably identical with the species *A. lonchitica*, which is common, in the form of impressions, at similar horizons. There is a considerable probability that the *Trigonocarpum* originally described by Hooker and Binney in 1854 and referred by Williamson to *T. olivæforme* (but apparently identical with *Trigonocarpum Parkinsoni* Brongniart), was the seed of *Medullosa anglica*. The petrified specimens of the seed are invariably associated with the rachis and other organs of the *Medullosa*, and there are certain points of structural agreement which confirm the probability of the attribution.

The seed is a large, ovate one, 40–50 mm. long; quite half the length, however, is occupied by the micropylar tube, the most remarkable feature of the seed. The testa consists of two layers—the outer sarcotesta, of delicate, partly lacunar tissue, bounded externally by a sharply differentiated hypoderma and epidermis, and the inner, ribbed, sclerotesta, consisting of dense, thick-walled tissue. The nucellus appears to have been free, from the chalaza upward, and terminates at the apex in a pollen chamber, provided with a distinct beak, as in the seed of *Cordaites*. The vascular system of the seed was double, the outer system of bundles traversing the sarcotesta, while the inner formed a complex tracheal network in the nucellus. The membrane of the megaspore is evident, but the prothallus has not yet been found preserved. The structure of the seed as a whole presents marked analogies with that of recent Cycadean seeds, the differences depending chiefly on the free nucellus, while in the Cycads it is adherent to the inner layer of the integument.

The attribution of the *Trigonocarpum* just described to *Alethopteris* is further rendered highly probable by Mr. Kidston's discovery of the seed of *Neuropteris heterophylla*, and I have little doubt that it is correct, though the direct proof of actual continuity has not

so far been obtained. In certain specimens of *Stephanospermum*, which has some points of resemblance to *Trigonocarpon*, the preservation is so complete as to show the pollen grains contained in the pollen chamber of the seed; the cell group, probably representing the antheridium, is clearly seen in the pollen grains.

Regarding the anatomy of the Medulloseæ (a family name provisionally taken as synonymous with Neuropterideæ), it may be noted that the structure of the Permian species is much more complex. The elaboration consists essentially in the differentiation of a central and a peripheral system of steles, the peripheral system sometimes forming a continuous, or nearly continuous, ring. As the secondary growth of the external steles was in some forms much greater on the outer than on the inner side, a certain resemblance to the stems of Cycadaceæ with medullary bundles is noticeable, accentuated in the largest stems of *M. stellata* by the appearance of extrafascicular zones of wood and bast inclosing the whole stelar system. Some authors, notably Mr. Worsdell, have laid great stress on these resemblances, which lead them to place the Medulloseæ on the line of descent of the Cycads. Personally, I have been unable to convince myself that the stem of the Cycadaceæ admits of an interpretation on "polystelic" lines, though on other grounds the affinity suggested has much in its favor.

While we have in the Permian Medulloseæ striking examples of the extreme complexity which this type of stem was capable of assuming, *Sutcliffia insignis*, a plant recently discovered in the Lower Coal Measures of Lancashire, carries us back to a type of structure probably more primitive than had previously been known in this family. The stem has a central stele of great size, without pith, the solid centripetal wood consisting of pitted tracheides interspersed with bands of parenchyma. From the principal stele, large vascular strands, the meristeles or subsidiary steles, are detached, which divide up and fuse with one another, ultimately giving rise to the leaf-trace bundles, a large number of which enter the leaf bases. The petiolar bundles are concentric, resembling those of Seward's *Rachiopteris Williamsoni*, which was no doubt the petiole of another species of *Sutcliffia*. In the specimen investigated, secondary growth in thickness was only just beginning. In habit and various structural details the plant agrees with a Medullosa; it shows a near approach to monostelic structure, for the single central cylinder forms a dominant feature in the vascular system, while the meristeles effect the transition to the leaf traces. The concentric bundles constitute a more Fern-like character than is known elsewhere among the Medulloseæ. The plant is of considerable interest, as indicating the probable derivation of the Medullosean stem from a simple protostelic type, such as occurs in *Heterangium* among the Lyginodendreæ.

As regards habit, there can be no doubt that the Medulloseæ were plants of very large size. Petioles of *Medullosa* nearly 15 cm. in diameter are known, and those of *Sutcliffia* approached the same dimensions. The repeatedly pinnate leaves, with the habit of a huge *Osmunda* (as in *Neuropteris*) or *Angiopteris* (as in *Alethopteris*), were borne on stems probably resembling those of Tree Ferns; in a *Medullosa* from Saxony the decorticated stem measures 48 by 46 cm. in diameter. The specimens of *Medullosa anglica* show that the stem was completely clothed by the decurrent bases of the leaves.

M. Grand'Eury's extensive observations on the association between fronds and seeds of definite species, not only in *Alethopteris* and *Neuropteris*, but in *Odontopteris*, *Linopteris*, *Lonchopteris*, etc., have convinced him that the Neuropterideæ generally were seed-bearing plants of Cycadean affinities. There can be no question that all the existing evidence points in this direction, while throughout the whole of the family there is practically an entire absence of any countervailing evidence on the Fern side.

We have as yet scarcely any knowledge of the nature of the male organs in this family. In 1887 Mr. Kidston described a form of fructification in *Neuropteris heterophylla*, the same species in which he afterwards discovered the seed. The specimen shows a forked rachis, bearing the normal vegetative pinnules below, while the branches terminate in four-lobed bodies, which may be interpreted either as groups of sporangia or as cupules. As there is no reason to suspect the presence of cupules in the Neuropterideæ, the former view is perhaps the more probable, in which case the specimen would no doubt represent the microsporangiate fructification; in no instance, as yet, are the indications perfectly satisfactory.

In the Neuropterideæ, as in the Lyginodendreæ, we are dealing with plants of which the anatomical structure is known, at least in certain representatives. We are therefore able to point to definite structural characters, quite apart from the habit, which indicate affinity with the Ferns, as we have already shown in the case of the Lyginodendreæ. In the anatomy of the Neuropterideæ with the *Medullosa* type of stem, the most Fern-like feature is the vascular system, which, in its primary "polystelic" arrangement is essentially Filicinean, and was compared by Weber and Sterzel with that of *Psaronius*. This character, it is true, becomes disguised as secondary growth proceeds, but the original ground plan of the structure is of unmistakable significance. The leaves, apart from the habit and venation, are on the whole of Cycadean structure and not, in themselves, much more Fern-like than those of the recent *Stangeria*. In the new genus *Sutcliffia* the anatomy of the stem, peculiar as it is, can only be compared with that of a protostelic Fern, while the concentric foliar bundles accentuate the Filicinean relationship. The

discovery of the *Sutcliffia* type of structure renders it probable that dialystely arose within the family Medulloseæ, and tends to separate the latter further from the Lower Carboniferous Cladoxyleæ; in this curious group there is the same combination of dialystely with secondary growth which we find in Medulloseæ, but the arrangement of the steles, and the nature of the tracheides, not to mention other characters, are quite different, and it seems most probable that the two families represent parallel lines of development. The Cladoxyleæ have been compared with Botryopterideæ, especially *Asterochlæna*, and an affinity in this direction appears highly probable. There is nothing, as yet, to indicate the particular group of primitive Ferns from which the Medulloseæ themselves may have sprung, but on anatomical grounds it seems not unlikely that they and the Lyginodendreæ may have had a common origin from simple protostelic forms.

OTHER PTERIDOSPERMEÆ.

There are at least two cases in which seeds have been found in actual connection with Paleozoic Fern-like fronds, where we have as yet no clue to the internal structure.

The first of these cases was described by Mr. David White in 1904, in a plant named by him *Aneimites fertilis*, from a Millstone Grit (Pottsville) horizon in West Virginia. The frond is a highly compound one, of the form familiar under the designation *Adiantites*, a generic name which has been discarded on technical grounds of nomenclature. The fructification is borne on the apices of branched. terminal extensions of the peripheral pinnæ, the cuneate pinnules being greatly reduced on the adjacent sterile portions of the frond. The small seeds are rhomboidal in form, lenticular in cross-section. and winged; it thus appears that they were of the platyspermic (bilaterally symmetrical) type. The author points out that the discovery of Pteridospermic characters in *Aneimites* throws serious suspicion on the sterile frond genus *Eremopteris* among others. My friends, Mr. Arber and Prof. F. W. Oliver, inform me that they have found strong evidence for the occurrence of seeds, comparable to those of *Aneimites*, in a species of *Eremopteris*.

A few months later, M. Grand'Eury (in April, 1905) made his striking discovery of the seeds of *Pecopteris Pluckeneti*, from the Upper Coal Measures of St. Étienne. In twenty specimens he found the seeds attached by hundreds to the fronds; they may occur on the ordinary, unmodified foliage, but where they are numerous the lamina is somewhat reduced. The small oval seeds (named *Carpolithes granulatus* by Grand'Eury nearly thirty years earlier) are attached to the ends of the principal veins, and are provided with a border or wing; their form is so similar to that of Samaropsis that they may

easily be confounded, in the detached condition, with this Cordaitean seed. The resemblance of the seeds of *Pecopteris Pluckeneti*, *Aneimites*, and (I believe) *Eremopteris* to those of the Cordaiteæ is a striking fact, showing that the bilateral or radial symmetry of the seed is of no value as a means of distinction between this Gymnospermous family and the Pteridosperms.

No paleobotanical discovery would be more interesting at the present time than that of the anatomical structure of *Pecopteris Pluckeneti*. The species is not typical of its genus, and was placed by Sterzel in a distinct genus, *Dicksoniites*, on account of his discovery of bodies which he interpreted as sori, and compared to those of *Dicksonia;* their nature is not yet clearly understood.

SYSTEMATIC POSITION OF THE PTERIDOSPERMEÆ.

The name Cycadofilices designated a group, only known at the time by its vegetative characters, which hovered in the gap between Filicineæ and Cycadophyta without showing any decided leanings to either side. The class name Pteridospermeæ represents a more advanced stage in our knowledge, and indicates plants which we know to have been already definitely Spermophytic, though retaining many marks of a Filicinean origin. This consideration appears sufficient to justify the institution of the new class.

The question remains, whether the Pteridosperms should be included under Gymnosperms or kept apart, at least for the present, as a subkingdom of their own. Many botanists will doubtless follow Professor Zeiller in choosing the former alternative. Personally, I incline to the latter, for reasons which I will now state. The question, it may be said at once, is largely one of convenience, for there can be no doubt of the Gymnospermous *affinities* of the group under discussion. So far as the seed is concerned, the Pteridosperms were Gymnosperms, on the same level with the Cordaiteæ. The only constant peculiarity of the seed is a negative one, the absence of an embryo, and this is common to the Cordaiteæ, which in all other respects were as highly organized as recent Gymnosperms.

If the Pteridospermeæ are to be kept distinct it must be on other grounds. The chief characters are the following:

1. The fact that the seeds were borne on fronds but little modified, as compared with the vegetative foliage. This appears to have been the case in every Pteridosperm where we have any evidence on the subject, and affords an important character, though a female *Cycas* no doubt only differs in degree.

2. The male organs. Like the female, they appear to have been borne on ordinary fronds, and, if we may judge from the one case

where they have been investigated, scarcely differed from the sporangia of certain Ferns. Here, so far as the evidence extends, there is a wide difference from any known Gymnosperms and a near approach to the Filicineæ.

3. The anatomical structure. There is probably no constant distinctive character in the structure either of stem or leaf. The anatomy of the stem in *Lyginodendron* does not differ esentially from that in *Poroxylon*, which appears to find its nearest allies in the Cordaiteæ, while other plants, such as *Pitys antiqua* and *Dadoxylon Spenceri*, which likewise possess primary centripetal wood in the stem, probably also belong to the latter group. It would not always be possible to tell from the structure of the stem alone whether a given plant belonged to the Pteridospermeæ or the Cordaiteæ. So, too, with the leaf. The anatomy of the petiole and lamina in *Medullosa* is essentially that of a Cycadophyte, while in *Lyginodendron* it is that of a Fern. Taking the *sum* of anatomical characters, however, the Pteridosperms, so far as we know them, are much more Fern-like than any typical Gymnosperm. We might frame a provisional diagnosis of the Pteridospermeæ as follows: Male and female sporophylls little differentiated from the vegetative foliage; no cones formed. Anatomy of either stem, or leaf, or both, of a Filicinean type, as was also the habit.

The chief practical reason for keeping the Pteridosperms apart from the Gymnosperms is their manifestly more primitive character, shown in one respect or another throughout the group. Even in the seed, the most advanced of their organs, possible primitive indications are not wanting. In *Physostoma*, with its integument breaking up into a ring of free tentacles taking the place of the micropylar tube, we have a unique form of seed investment. The characters of the male fructification, if we may take *Crossotheca* as a fair example, appear to have been frankly Cryptogamic, and the same applies to the anatomy of such plants as *Sutcliffia* and *Heterangium*, genera which show such evident relations to *Medullosa* and *Lyginodendron*, respectively, that we can not doubt their being Pteridosperms. It seems to me desirable to give full weight to primitive characters such as these and to keep the Pteridosperms distinct, rather than to merge them in the Gymnosperms, a group which has departed so much further from Cryptogamic traditions. At the same time I fully recognize that this is a matter of expediency rather than of principle, for further research will undoubtedly tend to fill up the gap between the two classes.

A more fundamental question is that of the relation of the Pteridospermeæ to the Cryptogams. All the characters in which the Pteridosperms show Cryptogamic affinities, whether in anatomical structure, in the morphology of the sporophyll, or in the nature of the male

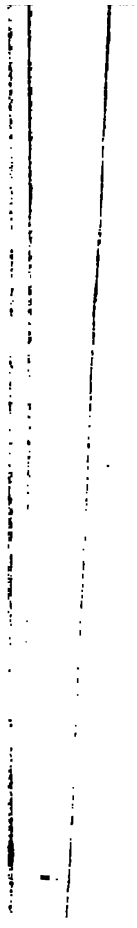
fructification, point clearly to their derivation from ancestors belonging to a Filicinean stock. They have been described as "Ferns which have become Spermophytes," and the phrase is appropriate. When, however, we come to inquire into the characters of the Filicinean group from which the Pteridosperms arose, we find that our data are insufficient. They are themselves, in all probability, as ancient as any land plants known to us, and their actual origin lies further back than our records at present extend. Considering that some of the Pteridosperms show a decidedly simple anatomical structure (as in *Heterangium*), we may assume that they were derived from plants of a simple type of organization. It would be rash in the extreme to identify any of the known "Primofilices" with the ancestors of the Pteridosperms; they are not nearly old enough geologically, and our knowledge is much too narrow to enable us to determine how far they may have retained the characters of the original common stock. The utmost we can venture to say is, that these simpler Paleozoic Ferns, the Botryopterideæ and their allies, probably stand nearer the Cryptogamic progenitors of the seed plants than any other group of which the record has come down to us.

Where we find among the Pteridosperms characters resembling those of more advanced Filicinean types, they are probably to be attributed to parallel development rather than to inheritance. The "polystely" of *Medullosa*, for example, if, as there is reason to believe, it arose within the Pteridospermic family Medulloseæ, was not a directly inherited Filicinean character, but rather a new development on Filicinean lines.

We may sum up the position of the question as to the derivation of the Pteridosperms in the statement that all the evidence points to their having sprung from the same stock with the Ferns. The antiquity of the Ferns, and especially of the comparatively simple types represented by the Botryopterideæ and related forms, appears sufficiently established to afford an historical basis for this conclusion.

VII. The Gymnospermeæ.

There is little of novelty to record in our knowledge of the Paleozoic Gymnosperms, as distinguished from the more primitive class Pteridospermeæ. With regard to the Cordaiteæ, the most important group, the position remains very much as Renault left it. Marvelous as was the reconstruction of this family at the hands of Grand'Eury and Renault, our knowledge urgently needs widening, and new data are to be eagerly sought. In the case of the Paleozoic Cycads and Conifers our records are scanty, and the time has not yet come for a general treatment of this part of our subject.



THE ZOOLOGICAL GARDENS AND ESTABLISHMENTS OF GREAT BRITAIN, BELGIUM, AND THE NETHERLANDS.[a]

By GUSTAVE LOISEL,

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The zoological gardens now existing in the world, with the exception of that at Schönbrunn, are all derived in some manner from our Jardin des Plantes. They were not established until a long time afterwards, since the oldest of them, that of London, was not opened until 1828, but they have all taken it for a model as regards their aviaries, cages, and inclosures, as well as in their museums and their laboratories. A proof of this is very explicitly given by Mr. Henry Scherren, in his book "The Zoological Society of London, A Sketch of its Foundation and Development" (1896, p. 19), and by Mr. Stanley Flower, in his report of a tour of which I shall speak further on. This origin is at once evident by comparing the drawings given by Mr. Scherren of the animal quarters in the London garden of 1850 with those which still exist, unchanged, unfortunately, in the menagerie of the Jardin des Plantes.

Though these foreign gardens were originally inspired by our old national institution, they have increased in size and during recent years have renewed the greater part of their old structures. For this purpose the directors or superintendents of some of these gardens have visited the principal countries of Europe in order to note and profit by the progress attained by other similar establishments.

In making this tour of inspection I did not confine my visits and studies to zoological gardens alone. I was charged to give attention

[a] Translated and abridged from the "Rapport sur une mission scientifique dans les jardins et établissements zoologiques publics et privés du Royaume-Uni, de la Belgique et des Pays-Bas," par M. Gustave Loisel. Extrait des Nouvelles Archives des Missions Scientifiques, t. xiv. Paris, 1907.

also to other establishments, public or private, where wild animals were reared either for the purposes of acclimation, of general zoology or of animal biology. I was therefore led to travel over England, Scotland, the Isle of Man, Ireland, Belgium, and the Netherlands, receiving everywhere the warmest welcome, not only from the scientists whose laboratories or experiment stations I visited, but also from the presidents or secretaries of societies, from the directors or superintendents of zoological gardens and from the great proprietors who opened for me their parks.

THE ZOOLOGICAL GARDEN AT LONDON.

The Zoological Garden of London belongs to the Zoological Society of London, founded in 1826 for the purpose of "the advancement of zoology and for the introduction into England of new and curious animals." The society performs this double function first by maintaining the garden which we are about to describe, then by publishing Proceedings (two volumes per year), Transactions (id.), the Zoological Record, a Guide to the Garden, and illustrated postal cards of the animals, finally by holding monthly meetings at which the fellows, the corresponding members and even strangers may present communications. These communications are submitted to a committee of publication which considers them carefully; thus, among 132 offered in 1905 only 86 were published in full, 84 in the Proceedings, 2 in the Transactions; the others were merely announced by title or by a concise abstract.

The society comprises at present 3,702 active members, 200 corresponding members, and 25 foreign members. It is administered by a council of 21 members, elected annually, among which are a president (the Duke of Bedford in 1906), six vice-presidents, a secretary, and a treasurer. The secretary (Dr. P. Chalmers Mitchell, F. R. S., at present) is the executive officer.

The council meets regularly every two weeks from January to the end of June and once a month during the remainder of the year; it publishes each year a report for the general session at which all members of the society may attend.

The total receipts of the society amounted, in 1905, to £30,421 6s. 9d. Among the details of these receipts I will mention the following:

	£	s.	d.
Admissions to the garden	17,469	6	4
Riding receipts (elephants and camels)	470	19	8
Sales of living animals	428	11	8
Sales of guides and postal cards	894	14	3
Rent from restaurant	1,000	0	0
Receipts from lavatories	72	8	1

The Zoological Garden is administered, under the general direction of the secretary, by a scientific staff comprising a superintendent, Mr. R. J. Pocock; a prosector, Mr. F. E. Beddard, F. R. S., specially charged with the conduct of the laboratory of comparative anatomy (prosectorium) attached to the garden; a pathologist, Mr. C. G. Seligmann, also attached to the prosectorium. * * *

The ordinary expenditures of the garden amounted, in 1905, to £22,435 15s. 8d., the principal objects being as follows:

	£	s.	d.
Rent, rates, taxes, etc	1,485	9	14
Salaries	4,356	8	10
Pensions	260	0	0
Provisions (including wages of storekeeper)	3,608	6	2
Cost and carriage of animals	1,124	11	6
Menagerie expenses	1,980	2	10
Expenses of the prosectorium	863	4	6
Maintenance of buildings, etc	3,901	1	11
Garden expenses	1,280	4	0
House and office expenses	322	13	1

The garden is situated in a portion of Regent's Park, occupying a space of 31 acres, for which the society pays an annual rental to the Crown. It is open to the public every week day from 9 a. m. until sunset; on Sundays and holidays only members and persons provided with special tickets are admitted.

It is divided by a canal (Regent's Canal) and a public road (Outer Circle) into three parts—the north garden, the middle garden, and the south garden, connected with each other by two bridges and a tunnel. On December 31, 1905, there were, in these three gardens, 2,913 vertebrate animals:

Mammals	689
Birds	1,554
Reptiles	560
Fishes	110

Invertebrates, variable number.

Of these 860 were acquired by gift, 286 by purchase, 286 were born, 1,097 were received on deposit, and 202 obtained by exchange.

During 1905, 514 animals died in the garden, 296 being mammals and 218 birds.

The animals are distributed in a most irregular manner, as is usual in all gardens of this character. This is doubtless due to the necessities of the case. In the following enumeration I shall, however, follow the usual zoological classification:

Mammals.—The garden contains a fine collection of monkeys and lemurs arranged so as to present examples of all the great natural groups. They are placed in three structures, each designed for a different purpose. * * *

The monkey house is a large edifice covered with glass, with numerous lateral windows opening upon flower beds. This house has along the sides separate cages for those species that can not dwell peaceably together and, in the center, a series of large cages common to several species. In this house are found most of the monkeys. (See pl. 1.)

The new ape house was recently constructed for the accommodation of the anthropoids at a cost of £4,000. It contains four large cages wholly separated by plate glass from the wide corridor where the visitors are admitted. This arrangement was intended to preserve the apes from any contact with the public, to prevent their being stuffed with bread or other food, and also to preserve a uniform temperature in the cages. I consider it, however, an inferior style of installation and think that it might be well to replace it, and this opinion is shared by the present secretary of the council. At the time of my visit this house contained six young chimpanzees and three orang-outangs. There were also in outside cages where the apes remain until evening, a young chimpanzee and three gibbons. (See pl. 1.) The lemurs are installed for the most part in a house which they share with the edentates. They thrive there very well and not infrequently breed; I even noted two hybrids from a crossing between *Lemur xanthomystax* and *L. ruffifrons*.

The carnivoræ occupy eleven separate structures. The principal one is the lion house, constructed in 1876 at a cost of £11,000. The body of this house is of red brick, 70 meters long and 21 meters wide; it has a wide corridor upon which wide windows open on the south side, while on the north side are fourteen large cages, each of which has two interior compartments, the latter being large dark dens which ought to be removed so as to give free access to the exterior cages.[a] Behind these dens there is first a long service gallery, then four great grilled cages projecting without the building in which the animals may enjoy the outside air. * * * (See pl. 1.)

The pinnipeds are represented in the garden by sea lions and seals, which live together in a very fine large inclosure constructed in 1905 (the sea-lions pond). This inclosure is occupied almost entirely by a large pond 1.80 meters in depth near the shelf from which the animals dive, and surrounded by shores either grassy or rocky. In the middle of the pond are three little islets and at its western end a large structure of rockwork in which are sleeping caverns for the animals. With these animals, giving a little animation to the scene, are a dozen penguins, which have bred here during the present year. * * *

[a] I learn recently from the secretary to the council that there are now being installed above the service gallery a certain number of bridges by which the animals may have free access to the exterior cages.

MONKEY HOUSE, LONDON ZOOLOGICAL GARDEN.

INTERIOR OF HOUSE FOR ANTHROPOID APES, LONDON ZOOLOGICAL GARDEN.

OPEN-AIR CAGE FOR LIONS, LONDON ZOOLOGICAL GARDEN.

The proboscidians are represented by four Indian elephants and one African elephant. Their house has a broad public corridor from which open eight large stalls. Without are two large paddocks with deep pools. In the same house are found a two-horned Indian rhinoceros, an enormous single-horned Indian rhinoceros, and a very young African rhinoceros. Another young Indian rhinoceros is in the Prince of Wales collection.

The tapir house, heated in winter, comprises a paddock and an interior stable provided with a large tank. It contains the two species of tapirs—Indian and Brazilian. Near this is a fine series of specimens of the zebra, including all the existing species, various species of wild asses, a Prjevalski's horse and a remarkable hybrid between Burchell's zebra and a mare, obtained from the Transvaal in 1902.

The swine family, such as the wart hogs, the red river hogs, the babiroussas, the peccarys, etc., are in a building that will no doubt soon be replaced by one better adapted to the needs of these animals. The female hippopotamus exhibited here was born in the garden in 1872; she is placed in a warmed stall which communicates with a tank nearly 3 meters deep and with an outer paddock which has another still deeper tank.

The giraffes, very delicate animals, requiring special care, are represented by a female of *Giraffa camelopardalis* imported from southwestern Africa, and by a young pair of *G. c. Antiquorum* from the Egyptian Soudan. These animals are placed in three large stalls, having the ground covered with fine sand, without litter (except for bedding), heated during winter to 10° C., and communicating with large inclosures open to them only in summer. * * *

Birds.—The Passeres or perching birds are represented by a large number of tropical species distributed in four aviaries.

The western aviary, 57 meters long, dating from 1851, but reconstructed in 1903, has fifteen separate compartments and a large central cage; each compartment has a retiring cage covered with glass which can be closed and heated in winter; in front of this is a little garden plat, part of which, covered with sand, has a little circular bathing pool, while the remainder, covered with grass, has three or four shrubs of various species.

The eastern aviary comprises a long row of cages which were repaired and improved last year and which can now be heated by a well-devised hot-water system. They serve as a permanent residence for a large number of tropical birds and as winter quarters for certain others placed during summer in other cages.

The birds of paradise and the humming birds are represented only by *Paradisea apoda*, *P. minor*, and *Cicinnurus regius*, which are placed

in the insect house. Other tropical insular birds are lodged in the parrot house. By the generosity of Mr. C. Czarnikow the Zoological Society has this year commenced the construction of a new aviary, which will be used exclusively for the shelter of delicate species.

The parrots are represented by a fine series of specimens that is doubtless the best collection of those birds to be found in any zoological garden. The house assigned to them was reconstructed in 1905; it comprises a central building with isolated cages and a series of large compartments with sandy bottom, some inclosed and some in the open air.

This house does not contain, however, all the parrots that the garden possesses. Some years ago it was found by trial that a number of individuals do better in the open air than in closed cages, and these are now kept in the canal bank aviary. This building, which is 25 meters long by 12 wide and 10–12 high, faces the canal; the southeast side is protected by a steep slope down which a stream runs from an artificial grotto; the three other sides are sheltered by large trees. Besides this a number of shelters against wind and rain are placed along the aviary. Artificial nests, where many species breed each year, are provided. The raptores or predatory birds are placed in five different aviaries. * * *

The aquatic birds (web-footed and wading birds) are scattered throughout the garden in at least fifteen different places. Certain species of geese, swans, and ducks are placed in localities so arranged that they breed regularly. The pelicans are usually represented by three different species; the penguins have been placed as I have already mentioned, with their natural associates the seals; other diving birds, the cormorants and kingfishers are placed in a house specially constructed so as to afford the public an opportunity of seeing how these birds pursue their living prey under water (the diving birds' house). A certain number of palmipeds and small waders live together in one of the best aviaries of the garden (the waders' aviary) in part of which bushes and rushes have been planted, while the rest is occupied by a small pond with shores of sand, gravel, or mud.

The greater part of the wading birds are kept, however, in two large aviaries called the great aviary and the southern aviary. The latter, which dates from 1905, contains rockwork so arranged as to afford a shelter to the birds and permit them to set on their eggs. The other, reconstructed in 1903, contains a number of shrubs and trees which give almost natural conditions to the birds that occupy it.

The most interesting gallinaceous birds in the garden are doubtless the brush-turkeys, which live in a large inclosure covered with wire, where they nest regularly every year. There is a fine collection of

pheasants in the northern pheasantry, the western pheasantries, and the eastern pheasantry.

Reptiles and batrachians.—These animals are not as well represented as the mammals and birds. The snakes, among which are some fine pythons and boas, the lizards, and some batrachians are placed in a house whose temperature is kept throughout the year at 24° C. The tortoises are in a neighboring building. These two structures have nothing especially remarkable as regards installation; they are covered with glass and contain a profusion of hot-house plants which gives them a most agreeable appearance. A number of chameleons are kept in the insect house.

Fishes.—The fishes are still fewer in number than the reptiles and batrachians, but they are represented by some forms that are very interesting from a zoological point of view.

Invertebrates.—These are represented by land crabs shown in the reptile house, by some insects, myriapods, and large, tropical spiders in the insect house. This house, which was completely rebuilt in 1903, occupies an area of about 60 square meters. Its interior is like a conservatory. In the center are the cages for the birds of paradise before mentioned. Around the walls are placed glass cases in which may be seen orthoptera and a certain number of lepidoptera in the state of eggs, cocoons, or butterflies.

BRISTOL ZOOLOGICAL GARDEN.

The zoological garden at Bristol belongs to the Bristol and West of England Zoological Society, a limited corporation founded in 1835. This society, whose only object is the maintenance of its zoological garden, was composed, in 1905, of 695 members, from which is elected an administrative council. This council is composed of a treasurer, who is the executive officer (Dr. A. J. Harrison), a secretary (Maj. G. F. Rumsey), and twenty-four members, who form committees on the menagerie, the gardens, entertainments, and finances. The council meets regularly every three months and publishes each year a report that is discussed at a general session.

In 1905 the total receipts of the society amounted to £7,223 9s. 2d. Among the items are the following:

	£	s.	d.
Admission fees and entertainments	3,312	2	6
Subscriptions	727	13	0
Restaurant	1,735	17	8
Sale of living animals	28	4	0
Sale of residue from provisions (skins, bones, etc.)	54	3	4

The garden is administered (under the general direction of the treasurer) by a superintendent, Capt. E. W. B. Villiers, who has

under his orders twenty employees, of which there are one head keeper and six underkeepers of animals. The total expenses of the garden in 1905 were £6,118, among which are the following:

	£	s.	d.
Salaries and wages	1,023	4	0
Food and litter for animals	549	18	7
Purchases of animals	70	10	0
Repairs	806	19	1
Expenses of gardening	388	14	10

The zoological garden of Bristol, or Clifton Zoo, as it is called in England, is situated at the foot of the plateau of Clifton, northwest of the city, in a retired and sheltered locality, occupying an area of 12 acres. It is open every week day from 9 a. m. until sunset.

Immediately on entering this garden one is struck with its fresh, park-like aspect, everything being well kept and pleasing. Indeed, it combines, as one may say, the best effects of a menagerie and a botanic garden. There are to be seen beds covered with geraniums,

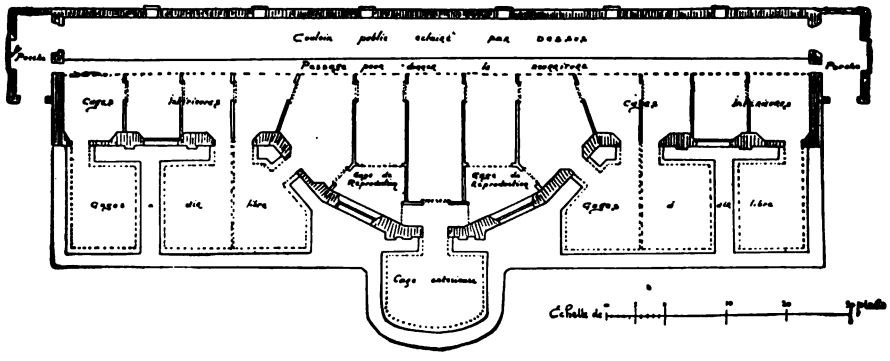


FIG. 1.—General plan of lion house, Bristol Zoological Garden.

fuchsias, yuccas, agaves, fan palms, etc., clumps of rhododendrons of various selected species, and a great number of ferns which together certainly form one of the finest collections in England.

In the center of the garden are spacious lawns where wild geese of many varieties wander at liberty, and a little farther toward the south is a fine lake with wooded islets which affords a home for waterfowl. Throughout the place clumps of indigenous or exotic trees tastefully surround the animal houses, which are themselves sometimes covered with ivy, wistarias, or wild grapevines. Here and there statues and ornamental vases add still more to the charm of the landscape. Besides, the trees and shrubs have been so chosen that the garden must appear in winter almost as bright as when I saw it during the month of August. There are in fact pines, cedars, araucarias, sequoias, and live oaks, mingled with ailantuses, sumacs, *birches, elms,* beeches, walnut trees, oaks, thorn trees, and especially *holly trees, of* which I was able to count twenty different species or

varieties. These varieties, which differ from each other in the coloration of the leaves or the fruit, were produced in this very garden either by predetermined selection or by the culture of accidental sports discovered in wild or cultivated plants.

The Clifton Zoo contained at the time of my visit 107 mammals, about the same number of birds, and a dozen reptiles.

The great *Felidæ*, represented by eleven lions, three tigers, one leopard, and two pumas, were placed in two large houses, which were found immediately to the left of the northern gate. The first of these houses, the new carnivora house, constructed five or six years ago, presents in front a series of fine large exterior cages freely open to the air both and above and upon three sides (pl. II). These cages, ornamented with colored glazed bricks, communicate with the cages within the house, which is lighted from above and has its walls like-

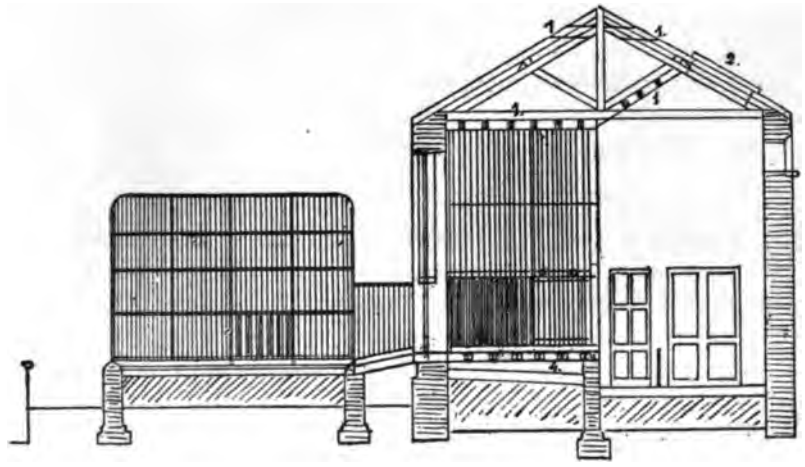


FIG. 2.—Transverse section of lion house, Bristol Zoological Garden.

wise faced with colored glazed brick, imparting an aspect of brightness and cleanliness that I did not often find elsewhere.

The second house for large *Felidæ* is a reconstruction (not yet finished in August, 1906) of the old lion house, which dated from the inception of the garden, and in which were exhibited the lioness Victoria, who gave birth to sixteen cubs in six litters (one, two, three, five, three, and two young), the lioness Lady to four, and the lioness Flo to six. In spite of these results, the administrative council resolved, in view of the age of the building, to reconstruct it, or rather to enlarge it, following the same general plan as that of the preceding building. But the council asked the architect to preserve in its primitive state the old façade, which had been covered with verdure by time. It is doubtless to this circum ıce that
the plan which I shown on figs. 1 and 2, and which ems
at the present time to serve as a model for structur

The monkey house, a little farther away, contained when I visited it some twenty specimens, and is constructed on the same principle of allowing the animals at all times access to a large exterior cage where the air can freely circulate on all four sides. However, a young male chimpanzee was placed in a glazed cage in the parrot house, and is rarely taken out into the garden.

The aviaries presented nothing especially worthy of note. A certain number of birds are allowed complete liberty; for example, a pair of American geese (*Bernicla magellanica*) nest every year in one of the thickets of the garden. I also noted two Benin owls (*Bubo lacteus*), magnificent, rare birds, that come from one of the hottest regions of the globe, and which nevertheless have for six years done very well here in a small cage without artificial heat and exposed freely to the southwest wind.

In the reptile house, near that for the parrots, was a pair of boa constrictors, the female of which brought forth in July, 1898, a litter of twenty-six young and since that time has borne three other litters of thirty-five, thirty-one, and fifty. Some of these have died; the garden has sold the others, keeping only a young female to replace the mother, who died last year. * * *

ZOOLOGICAL GARDEN AT MANCHESTER.

The Zoological Garden at Manchester (Bellevue Gardens) is a private enterprise, originating as far back as 1829. At that time a certain John Jennison installed at Stockport, 10 kilometers from Manchester, a little menagerie which he exhibited to the public for an admission fee. Some years afterward he abandoned this first establishment to buy southeast of Manchester some 80 acres of land, where he reinstalled his enlarged menagerie and added a large number of attractions, which his sons, the present proprietors of the garden, have since further developed.

Bellevue Gardens can hardly be compared with the zoological gardens of London, Dublin, and Bristol. They form indeed a vast, permanent fair ground, open every day to the public from 9 a. m. to 11 p. m., visited on holidays by 35,000 to 45,000 persons.[a] An enumeration of its principal attractions will give a feeble idea of the activity that prevails. I found there indeed numerous bars and restaurants, large ball rooms and dancing platforms, a museum, a moving-picture exhibit, a "jungle" shooting range, riding horses, pleasure boats and mechanical velocipedes, a maze, a tennis court, a ground for athletic exercises, a very curious panorama representing the city of Delhi, an immense wooden structure arranged in the form of an amphitheater on the bank of a broad water course representing the Jumna, an affluent of the Ganges, on which plies a little steamer for

[a] The admissions number about 1,000,000 per year.

EXTERIOR CAGES FOR THE LION HOUSE, BRISTOL ZOOLOGICAL GARDEN.

AQUATIC POND AT WOBURN ABBEY.

the accommodation of visitors; an artificial lake 8 acres in extent and on which are likewise two steamers and numerous pleasure boats; kitchen gardens and pleasure gardens, nurseries, a toboggan slide, conservatories, etc.

In the midst of such diverse attractions as these are found the 200 cages, yards, or pools of the menagerie in which are daily fed nearly 1,000 animals (250 mammals, 600 birds, and 60 reptiles), some of which merit our attention.

The monkey house in particular is perhaps the finest one now existing in the gardens of Europe. It is a large structure of Moorish style, widely lighted and ventilated from above and from the whole of the western side, but not heated throughout during winter. It contains first a large central cage, 27 meters long by 5.50 meters wide, in which there are some fifty monkeys, principally baboons and macaques. As a peculiarity of this cage I noted the presence of various playthings which seemed to me very useful for satisfying the need for movement and intellectual activity of the animals; there were rattles, bells, rocking horses, trapezes, balancing poles, hanging ropes, a large wheel and turntables, a pigeon house and a well with a pump, by means of which the monkeys could draw water for themselves, a dumb waiter by means of which they could draw up seeds and other dainties; finally a little house with open doors and windows, which was the only place heated during the winter.

This central cage is surrounded by a broad public corridor, in which are hanging baskets or pedestals for green plants or flowers; along each side of the building is a series of cages communicating with out-door cages. Two of these lateral cages thrown together form an apartment for a young Kooloo-Kamba chimpanzee; one of these cages has a warmed retiring cage, in the form of a long box, in which the animal generally passes the night; the other chamber, containing a certain number of playthings with which he occupies most of his time, communicates with the corresponding exterior cage.

There are still other installations for the monkeys (of which a new species of chimpanzee and a hamadryas baboon have bred) situated not far from this large house. I again noted here the increasing tendency to place the animals in the cold open air;[a] a treatment not

[a] I received, at the end of last January, a letter from Mr. Jennison saying that his chimpanzees continued in very good health, and that they still, at that time, passed a part of their life in the open air. He informed me at the same time that he was about to add to the great monkey palace an open-air cage having the dimensions of 8 by 8 by 5 meters. Besides, all the windows on the west side of the palace have been taken out, so as to permit the exterior air to have free access to the very interior of the house. Mr. Jennison adds, "Indeed we have remarked that not one of our monkeys that live in the open has ever suffered from paralysis of the lower limbs, which is fatal to so many of our other monkeys."

confined to monkeys alone. The house in which the elephants are kept (these animals being utilized in the garden, especially as performers, in the great pantomimes with fireworks which are exhibited on holidays in the panorama of Delhi), also that for the rhinoceroses and hippopotami, is never heated during the winter, and the reservoir from which spring water is drawn for the bath of these animals is often covered with ice, yet this does not appear to have any bad effect upon their health. Then, too, the pumas have been living for some years in cages where the ground is covered with snow in winter, and the spotted hyenas that fell sick in warmed houses recovered their health when they were given this new, open-air treatment.

However, as a survival of ancient errors, the house for the *Felidæ*, where I noticed among other animals a beautiful tigress, born here in May, 1900, is constantly heated to 20° to 22° C. Still, I note that the cages in this house are large and well ventilated. They are also decorated with fine mural paintings. The lionesses have bred here occasionally.

The cage for large nonpoisonous snakes is heated to a temperature of 27° to 32° C., but this is, unless proof to the contrary is forthcoming, a necessity justified by the good results obtained. This cage communicates freely with a small conservatory kept very humid and having a luxuriant vegetation; it is itself a spacious hothouse, 23.8 meters long by 3 meters wide and 3.65 meters high (pl. III); its floor, of wood, raised about 1 meter above the ground, and pierced by ventilating flues protected by grillage, covers over a sort of cellar in which are the conduits for heat and water; the latter are surrounded by small hot-air pipes so that they constantly deliver tepid water to the large basins frequented by the pythons. When I saw them, the snakes did not present at all the torpid aspect that is usually seen in such collections. When I entered their cage to photograph them the keeper seized some of them to place them as I wished and it was really curious and somewhat terrifying to me, who was not accustomed to it, to hear their repeated hissing and to see with what vivacity they ran along the ground, climbed the tree or swam about in their basin. There were there a few small nonvenomous snakes and about thirty boas and pythons, some of which were 20 feet long. They eat every three weeks, winter and summer, or rather at such periods there are offered to them kids, sucking pigs, rabbits, guinea pigs, chickens, etc. Many of them copulate, and sometimes eggs are laid which, however, have not as yet been hatched, although the females set upon them constantly; thus, in April, 1904, a large python remained for two months coiled about a nest of fifty eggs without any result.

REPTILE CAGES, MANCHESTER ZOOLOGICAL GARDEN.

This snake cage was also provided with trunks of trees, and it was further ornamented by flowers and green plants upon which were climbing green and gray lizards or chameleons from northern Africa, and among them there flew about cardinals with their red heads. If I add that numerous globes of electric light illuminate it until 11 p. m., when the snakes, nocturnal animals, are in full activity; if I say further that the visiting public finds itself in a hothouse where is cultivated a part of the Mediterranean flora, I would give but a feeble idea of this beautiful installation, which I did not find equaled in other gardens.

There are still other installations of animals at Manchester, which repay a visit. I will mention a basin for sea lions that communicates with a large covered fish pond having seats about it like an amphitheater. Here the public may witness the droll evolutions of three California sea lions that climb stairways, jump off an elevated platform, jump over perches or through hoops, hold on to trapezes, etc.

PRIVATE MENAGERIES AND PRESERVES OF WILD ANIMALS.

A very large number of English and Scotch proprietors like to keep wild animals near their homes. Some of them, such as Sir Cl. Alexander, at Faygate Wood, Horsham, Sussex, and Sir Robert Leadhatter, at Hazlemere (Bucks), have veritable menageries, with lions, pumas, leopards, hyenas, or wolves; others prefer aviary birds, such is Sir D. Seth-Smith, who possesses about 200 foreign birds. Most of the other large proprietors raise in their parks deer, gazelles, moufflons, goats, and exotic sheep, as well as cranes, flamingoes, rheas, cassowaries, eagles, and owls.

Many of these parks are vast expanses of meadow or wood, taken from the old forests and inclosed by walls or fosses at the time of the Norman conquest. In a certain number of them openings have been made in such a manner that the deer of the neighborhood can easily enter, but can not return.

In Whitaker's Almanac for 1892 there are enumerated 395 of these parks, inclosing 68,331 head of fallow deer and 5,477 of red deer, in England alone, without counting those of Scotland and Ireland. I could not think of visiting them all, but some of them deserved attention, either because of their special interest or of the importance of their collections.

Preserves for wild cattle.—I thought best to first seek those antique parks where still live some herds of wild cattle, descendants, if we may believe Sir Walter Scott (who appears to have been mistaken), of those *Tauri silvestres* or aurochs, which were, as he says in one of his poems—

> Mightiest of all the beasts of chase
> That roam in wooded Caledon.

Of these parks, that of Chillingham, which belongs to Earl Tankerville, and which, situated to the south of Berwick-on-Tweed, was on my route to Scotland, seemed the most important and the most interesting to visit, were it only on account of its magnificent castle and the collections which it contains.

The park, surrounded by a stone wall built in 1220, has an area of 1,200 acres; its upper part, in which the fallow deer, red deer, and wild cattle live, is composed of sandy flats, ravines, and wooded hills, to which the animals usually retire during the day; its lower part, separated from the other by a fence, has large grassy plains, where the animals pasture during the night, the gates being left open after the forage has been gathered. During the winter there are left on these meadows bundles of hay which the animals seek out and eat.

The wild cattle of Chillingham have, at birth, a pure white pelage, which afterwards becomes creamy white; but the muzzle, hoofs, and ends of the horns are black; the ears are reddish brown and the hair on their interior is brown. The eyes have long lashes, which gives to their gaze a depth and peculiar character. The forms of their bodies are harmonious, their backs are horizontal, and their shoulders are broad. The skin is thin and the weight of the skeleton light in proportion to the total weight of the body.

These animals lie down for the greater part of the day, not usually descending to their pastures until night. They are active in their movements and in speed of running can rival a horse. They are extremely strong, and one of these cattle imprisoned in a small inclosure has been known to jump out over a gate 2 meters high without breaking it.

The Chillingham herd is now composed of about 60 head; this has been the constant average for a number of years. There are 30 to 40 cows, 15 to 20 bulls, and 7 or 8 calves. They live all together, moving from place to place under the command, as it appears, of a leader bull. When this animal reaches a certain age, an average of 8 years, he has to defend himself against the younger bulls, who wish to dethrone him; violent combats then take place, and the conquered, who is generally the old one, is chased from the herd, in which he is never seen to regain his place; he remains solitary and, as in that state he is extremely dangerous, he is killed.

When the bulls are too numerous an attempt is made to capture some of them by placing food in a small inclosure; when they have entered they are lasooed and castrated; when these oxen are again given their liberty they rejoin the herd, where they are always well received.

The cows begin to calve at about 3 years of age and live, on the average, about 14 years. They abandon the herd for a time to give birth to their young and to suckle them, keeping charge of them until

they are 2 years old. It sometimes happens that young calves are abandoned and trampled on when the herd becomes frightened and runs away; some of them die, others are found wandering in the woods, and can then be easily caught by hand, but it is useless to capture them for preservation, as they become too dangerous.

From 1875 to 1886 there were made at Chillingham crosses between the wild cows and domesticated short-horn bulls. The hybrids thus obtained had a pelt of the wild type, but the black color of the nose was replaced by a flesh color or marbled tint, and the brown hairs of the ears were more developed. These individuals were still of the wild type; they had the muscular vigor, the lightness of bones, and the fine carriage due to the special development of the shoulders. On the other hand, their meat was superior to that of the Chillingham oxen, their weight was heavier, and their development more rapid.

It should be noted that these hybrids have never had any contact with the wild herd, so that the race of the Chillingham cattle has always remained absolutely pure.

When I left Glasgow to return to England I also found upon my route another preserve of wild cattle, the park of Cadzow, situated 13 miles from Glasgow, near Hamilton. This park, which belongs to the Duke of Hamilton, is a little larger than that of Chillingham, but the stone wall that surrounds it on all sides dates only from the beginning of the nineteenth century. It has an extent of 1,471 acres, of which 921 are pasture land, 23 in river and 527 in forest, where one may see magnificent oaks centuries old. This wood is the remains of an old forest that extended on the east as far as the North Sea, the park at Chillingham representing its eastern extremity. The park at Cadzow has no ponds, marshes, nor hills.

The cattle of Cadzow have, like those of Chillingham, a white pelage with a black muzzle; but their ears and fore feet are sometimes also black. One of these cattle was exhibited for a few days at the London Zoological Garden.

The bulls have a very broad forehead and a long face, the shoulders and fore part of the body are heavy, the neck arched, the flanks and posterior part of the body light; their height at the shoulder is 1.62 m. The cows are smaller than the bulls, but they have the same general form; it is to be noted only that their rather narrow nose enlarges as it approaches the muzzle.

Cows from the Cadzow park have also been crossed several times, first with the Chillingham bulls and then with bulls from Wales.

These cattle are not allowed to run throughout the whole extent of the park; they are confined in three large plains of 180 acres, one of which had 20 adult cows, the second 10 cows and 5 heifers, the third 8 adult and 5 young bulls. During the summer these animals remain night and day in the fields; in the winter some of them seek

shelter in sheds built for them, but others merely pass the night under the trees.

The cows have their first young at 3 years; when calving they always isolate themselves from the herd and keep their calves hidden for several days, during which time they are very dangerous. The calves are weaned at the age of 6 months.

The cows are killed when they reach the age of 10 years and the bulls according to circumstances. The bulls sometimes fight with each other. The herd also sometimes turns upon some individual and kills it or at least forces it to keep away; after a while such a one sometimes succeeds in regaining his place in the herd.

Park of the Duke of Bedford, at Woburn Abbey.—The chateau of the Duke of Bedford, situated to the southeast of the city of Bedford, is surrounded on three sides by an interior park in which I noticed an inclosure where young ostriches were living and a large pond devoted exclusively to the raising of goldfish. This pond is surrounded by a horizontal grillage 1 meter broad to prevent the aquatic and struthious birds from interfering with the fish; they catch their feet in the network of the grillage and hasten to abandon such an uncomfortable place.

The western front of the chateau looks out upon the large park, which covers a surface of 2,837 acres, extending around the grounds above mentioned. It comprises an undulating plain (1,464 acres), woods, heaths, and 50 acres of water distributed in twelve large ponds and many small ones.

I arrived at Woburn unexpectedly. Her Grace the Duchess had not been able to group the animals in the park as she had intended to do for me; the time that I could afford for my visit was only sufficient for a rapid survey of a portion of the park, during a drive behind two beautiful horses, and yet the spectacle was such as but few persons have ever been permitted to behold.

Leaving the chateau by the great north door, we immediately entered a vast, grassy plain upon which we saw great herds of ruminants which fled at our approach. I recognized there bands of deer of several species, llamas, zebus, yaks, etc.

Proceeding in a northerly direction, we perceived, lying down in a valley, a herd of red deer at rest, in which I was able to count 150 to 160 head.

A little farther we came upon flocks of ostriches, emus, and rheas, and reached the region where certain species are confined in grassy paddocks of considerable extent and almost all provided with shelters. I found there some 30 Cape elands (*Taurotragus oryx*) in an inclosure of 44 acres; then some specimens of *Cervus duvaucelii* and *Cervus eldii;* banded gnus, camels, moufflons, and argali sheep. In a corner of one of the inclosures a great bustard was sitting on her nest.

Directing then our course toward the east, we found in complete liberty herds of white deer, white-tailed gnus, wapiti deer, then a herd of bison, of Russian aurochs, a dozen hanguls (*Cervus cashmirianus*), and some 40 wild ducks that breed here regularly every year.

After 3 or 4 miles there were on our left other inclosures in which were tapirs, giraffes, some 15 Prjevalsky horses, 8 Grevy and Burchell zebras, onagers, hemiones, and kiangs in an inclosure of 11 acres; then we came to a sandy plain covered with ferns in which bands of kangaroos of several species were jumping about, fleeing at our approach.

The Prjevalsky horses came from a herd of 26 young ones, imported for the first time alive into Europe by C. Hagenbeck. At the instance of the Duke of Bedford, Hagenbeck sent, in 1900, an expedition to the mountains of Ektala, near Kobdo, in western Mongolia. Some 50 colts but a few days old were easily captured by the lasso; they were nursed by Mongolian mares, then sent to Europe, where only 26 arrived alive.

We then traversed an undergrowth where we found still more herds of *Cervidæ*, for the most part *Cervus porcinus*. A little farther in a grassy plain I perceived a band of wapitis (*Cervus xanthopygus*), imported from Manchuria by the Duke of Bedford, and which have bred in the park.

Then, returning to the chateau, we passed not far from a large pond in which I admired many species of cranes, among which were some magnificent blue cranes, flamingoes, ibis, barnacle geese, with innumerable flocks of other geese, ducks, and swans. (See pl. II, from a photograph furnished by the Duchess of Bedford.)

The last printed list of the animals of the park at Woburn Abbey, made in 1905, and including mammals only, comprised a total of 783 *Cervidæ*, 89 antelopes, 23 wild goats, 41 wild sheep, 47 *Bovidæ*, and 25 *Equidæ*, all exotic species. These figures are probably less than the actual number, for it is almost impossible to enumerate with precision herds of such animals as *Cervus porcinus*, that live in the wooded portions of the park. Besides, at the time of my visit to Woburn that number had been considerably exceeded by reason of the numerous births that occur there every year.

As to the birds, the number of individuals living freely in the park must be quite as great as that of the mammals, judging from the aspect which a view of the ponds presented. An approximate list of the birds made at the end of November, 1906, which was kindly sent me by the Duchess of Bedford, gives a total of 91 swans (comprising 7 species or distinct varieties), 324 geese (18 species or varieties), 50 sheldrakes, (5 species or varieties), 81 rheas (3 species or varieties), 3 ostriches, 3 emus, 3 pelicans, 66 cranes (10 species or varieties), 8

flamingoes, 10 bustards, 7 ibises, and 6 guinea fowls. There should be added to this list a large number of pheasants, partridges, exotic pigeons, and especially flocks of ducks (21 species or varieties) that it was impossible to count.

The above description may perhaps give some idea of the extensive experiment in acclimation commenced by the Duke of Bedford fifteen years ago, and which could not have been carried on in any zoological garden. This experiment is still going on, and it is to be hoped that it may be continued for a long time. It has, however, been in operation long enough to enable us to draw certain conclusions. Considering the results obtained with the animals introduced at Woburn, we may group them under four heads, as follows:

SPECIES NOW INCREASING.

Name of species.	Individuals imported.[a]	Born.	Present November, 1906.[b]	Where confined, etc.
Cervus elaphus barbarus Benn	8 (1898)	15	19 (1)	In a large grassy inclosure.
C. el. maral Og	16 (1897)	111	65 (13)	The same. Very resistant.
C. (Pseudaxis) sika Temm. & Schl.	31 (1893)	149	109 (9)+	In the great park. Very resistant.
C. S. mandchuricus Sw	22 (1894)	41	29 (12)	Do.
C. (Pseud.) taevanus Blyth	5 (1897)	10	17	Do.
C. (Pseud.) hortulorum Sw	91 (1895)	148	114 (8)	Do.
C. unicolor Bechst	25 (1894)	62	35 (3)	Do.
C. porcinus Zimm	27 (1894)	11	49+	In the woods. Can not be exactly counted.
C. axis Erxl	44 (1893)	149	81 (1)+	In great park. Bear yearly.
C. duvaucellii Cuv	22 (1897)	37	37 (1)	In grassy inclosure, with shrubbery.
Elaphurus davidianus A. M. Edw	18 (1894)	38	37	The same. Some died of an acute inflammation of the bowels of unknown cause.
Cariacus americanus Erxl	140 (1894)	44	26	Mostly in the wood, where they do well; the number 26 relates to those kept in the park, where they do not thrive.
Moschus moschiferus L	61 (1894)	(?)	(?)	Did badly in park. Placed in wood, thrived so that they could not be counted.
Cervulus muntjac Zim	98 (1893)	(?)	(?)	Do.
C. reevesi Og	24 (1894)	(?)	(?)	Do.
Capreolus pygargus Pall	26 (1898)	(?)	(?)	Do.
Tuurotragus oryx Pall	19 (1895)	54	43 (10)	In large inclosure, with shelter. Fed on hay, clover, and maize.
Boselaphus tragocamelus Pall	16 (1892)	62	38	In park in summer, in inclosure with shelter in winter.
Cobus sing-sing Benn	12 (1896)	21	17 (1)	In the park, with shelter.
Hemitragus jemlaicus H. Sm	23 (1894)	55	19 (42)	In the park.
Capra hircus var. L	3 (1901)	3	5	
Ovis aries L	8 (1901)	7	16	
Bos taurus (var. pygmy) L	14 (1894)	13	17	In the great park.
Bos (Bison) bison F. Cuv	7 (1896)	19	26 (5)	In a large grassy inclosure. Clover hay, and maize in winter.
Lama glama L	7 (1897)	10	9	In great park. Their coat is thicker in summer.

[a] In parenthesis, year of importation. [b] In parenthesis, number sent to other parks and gardens.

Imported American gray squirrels have multiplied and now number some hundreds.

SPECIES THAT APPEAR TO BE STATIONARY

Names of species.	Individuals imported.	Born.	Present November, 1906.	Where confined, etc.
Cervus cashmirianus Falc	14 (1898)	5	11 (1)	Do not do well on grass; better on gravel.
Rusa Aristotelis equinus Cuv	15 (1895)	15	15 (1)	
Rusa nigricans Bro	4 (1899)	14	4	
C. sika (var.)	2 (1900)	3	2	
C. hippelaphus typicus Cuv	11 (1895)	8	8	
Odocoileus mexicana Licht	6 (1900)	11	8	In grassy inclosure, with shelter.
Connochætes taurinus Bur	4 (1897)	6	5	
Ovis musimon Sch	19 (1894)	41	14	In large grassy inclosure.
Poephagus grunniens L	13 (1895)	12	6	In great park, where they can no longer be counted.
Bos (Bison) bonasus L	4 (1900)	.....	4	In large grassy inclosure.
Camelus bactrianus L	3 (1898)	1	3	Do.
Equus burchelli chapmani Lay	5 (1895)	3	3	In great park in summer, in inclosure in winter.
Equus grevyi	4 (1902)	.....	4	Do.
Asinus kiang Moor	3 (1894)	.....	4	In large grassy inclosure
As. onager Briss	2 (1903)	.....	2	Do.
As. hemionus Pall	1 (1903)	1	1	Do.
As. asinus (var. pygmæa) L	4 (1903)	4	4	Do.
E. prjevalskii Pol	14 (1901)	3	15	Do.

SPECIES NOW DECREASING.

Cervus xanthopygus A. M. Edw	24 (1896)	37	2 (19)	In grassy inclosure.
C. canadensis Erxl	76 (1893)	32	5 (2)	Do.
C. canad. asiaticus	37 (1896)	33	9	Do.
C. bactrianus	8 (1899)	1	1 (3)	Do.
C. sambar unicolor (var.)	19 (1896)	9	2 (6)	Do.
Hippelaphus moluccensis Q. & G	15 (1894)	4	6 (2)	Do.
C. alfredi Sclat	2 (1899)	4	1	Do.
Rucervus eldii Guth	46 (1896)	28	27	In grassy inclosure, with shelter.
Dama mesopotamiæ Broo	3 (1903)	28	1	Only females imported.
Connochætes gnu Zim	4 (1896)	1	2	In grassy inclosure, with shelter.
Saiga tartarica L	19 (1902)	12	3	Six died in winter, refusing to eat hay and cereals.
Giraffa camelopardalis L	4 (1902)	12	2	In a grassy court in summer, in a warm stable in winter.
Ovis nahura Hod	20 (1893)	2	1	
Bos (Bubalis) depressicornis	5 (1896)	2	3	In large inclosure, with shelter.
Lama pacos L	6 (1906)	2	2	In great park. Mortality partly due to want of food in winter.
Petrogale penicillata Gr	14 (1902)	1	2	In great park. Now being attacked by an epidemic malady of the liver that seems to be always fatal.
Halmaturus ruf. benetti Wat	26 (1894)	25	10	Do.

SPECIES THAT ARE EXTINCT.

Rangifer tarandus L	25 (1894)	1	.....	Do not thrive on grass. Died, although moss was given them in abundance.
Alces machlis Og	25 (1895)	.....	.....	In great park, where they found leaves and branches, but very few birches and firs. One alone lived more than a year.
Blastocerus paludosa Desm	9 (1897)	1	.....	In a sanded inclosure.
Pudua pudu Mol	4 (1903)	1	.....	In sanded inclosure, with shelter, in summer; in inclosure, with warmed stable, during winter.

SPECIES THAT ARE EXTINCT—Continued.

Names of species.	Individuals imported.	Born.	Present November, 1906.	Where confined, etc.
Blastocorus campestris F. Cuv	6 (1894)	1	.....	
Mazama, sp. var. (Brockets)	17 (1894)	1	.....	
Cariacus macrotis Say	23 (1897)	1	.....	
Capreolus capræa Gr	93	1	.....	Sent into the wood, where all died.
Capreolus mandchuricus	23	1	.....	
Strepsiceros capensis Har	4 (1899)	1	.....	In a grassy inclosure, with a shelter; one female lived 5 years.
Antilope cervicapra Pal	13 (1895)	13	.....	The young, born in winter, died of cold.
Hippotragus niger Har	4 (1895)	1	.....	
Cephalophus grimmia L	3 (1895)	1	.....	
Cervicapra arundinum Bod	2 (1896)	1	.....	
Antilocapra americana Ord	14 (1895)	1	.....	
Oryx leucoryx Pal	5 (1896)	1	.....	
Bubalis bubalinus	5 (1896)	1	.....	
Tetraceros quadricornis Bl	6 (1895)	1	.....	
Ovibos moschatus Zimm	2 (1899)	1	.....	One lived nearly 4 years.
Rupicapra trágus Gr	7 (1894)	1	.....	
Gazella subgutturosa Guld	17 (1897)	1	.....	
Capra falconeri Wag	8 (1900)	4	.....	
Urotragus goral Hard	13 (1897)	4	.....	
Ovis ammon L	15 (1901)	3	.....	In a rocky paddock.
Ovis tragelaphus Desm	3 (1893)	.....	.....	Taken sick with foot-rot.

The foregoing tables show in a general way that the *Cervidæ* imported from America have given the least satisfactory results.

All the species that are noted as being kept in inclosures with shelters are fed during the entire year with grass, wheat, and other cereals; during the winter there is added to their ration of hay, clover, acorns, hazel-nuts, and branches for the bark on them.

The greatest mortality is due to cold and dampness, affecting especially the young, or to the development of parasites in the lungs or stomach. It should, however, be noted that the axis deer, the sambars, the swamp deer of India, Duvaucel's deer and the pig deer appear to be able to resist parasitic maladies; they are the species that have thriven best at Woburn Abbey.

In brief, the vast experiment in acclimation which the Duke of Bedford has carried on at Woburn Abbey since 1892 has extended to 1,600 exotic mammals and their descendants belonging to 100 different species; and besides this he has had representatives of 80 species and varieties of foreign birds of which it is impossible to give the exact number of individuals.

If we add, further, that the Duke of Bedford preserves and succeeds in propagating species about to become extinct in their native countries, such as the elands, that have since 1895 brought forth 34 young, the American bison, that have produced 29, and Father

David's deer (*Elaphurus davidianus*), that produced 38, and finally, if we note that these numerous births enable the Duke to enrich each year the collections of the zoological gardens of England, and even that of our Jardin des Plantes, we may say with perfect truth that not only does acclimation but zoology proper owe much to the president of the Zoological Society of London and to the Duchess of Bedford, who also interests herself with intelligence and activity in the work going on at Woburn.

Tring Park.—The origin of the zoological collections at Tring Park goes back some thirty years at the time of the youth of Sir Lionel Walter Rothschild, eldest son of the great English banker. When quite a child Lionel Walter loved to collect butterflies and birds that he found in abundance upon the large estate that his father possessed at Tring, and which he also procured by purchase. His collections gradually increased to such proportions that he conceived the idea of establishing at Tring a great scientific establishment now known as the Museum; at the same time be made some experiments in acclimation in the park of the chateau and at Dundale, one of its dependencies.

Dundale is a small estate situated a few minutes walk from the Museum; there is there a small park with a large pond where a certain number of webfooted birds breed every year. Many hybrids have been thus obtained, as well as melanistic and albino individuals. He has never had there, however, a regular station for experimental zoology, as I had supposed, and when I was there it was with difficulty that I could discover a few ducks swimming about in the clear water among aquatic plants.

The animals that feed upon the extensive undulating plain in front of the park of the chateau of Tring are likewise not placed there for the purposes of study. There is there a flock of 17 emus (*Dromaeus* and another of 15 rheas (*Rhea americana and darwinii*), that, impelled by curiosity, came forward to meet me when I entered the park. Farther on (pl. IV) I met, at the edge of a pond, some solitary emus and, on the right, in a slight hollow, a herd of kangaroos, that, sitting up in order to examine me better, allowed me to approach near enough to photograph them; I recognized the great kangaroo (*Macropus giganteus*), which thrives extremely well on the grassy plains of the park, and Bennett's kangaroo (*M. Halmaturus Bennetti*), which especially affects the wooded portions. Continuing my walk, I perceived at a distance a herd, comprising about 150 head, of Japanese deer (*Cervus sika*) and fallow deer. Finally, going toward the forest that bounds the park on one side, I reached an inclosure where was an ostrich with its young and a large pheasantry where

there are raised every year numerous pheasants and partridges for hunting purposes.

The kangaroos, as well as the deer, pheasants, and partridges, are in perfect liberty and seek and find their own food. They are never housed during winter, and it is only when the ground is covered with snow that any pains is taken to supply them with food; the emus and rheas alone have food given them during the entire year. All breed in a normal manner, and at the time of my visit, July 25, 1906, the female kangaroos had young in their pouches, a rhea was brooding seven little ones born five days previously and I succeeded in photographing a male emu who was followed by a single chick two weeks old. I will add that at Tring, as elsewhere in Europe I believe, the young broods of rheas and emus suffer a heavy mortality; the adults, on the contrary, stand our climate perfectly well, but sometimes show phenomena of total albinism, of which I have seen three cases. As to the deer and kangaroos, they rear their offspring perfectly well, and at Tring the multiplication of deer is so rapid that a certain number have to be killed each year.

Last year, at Tring, one could admire a pair of Prjevalsky horses; unfortunately the male has since died. The female, bred to one of the stallions of the Duke of Bedford's stock, has given birth to a colt which is now as large as his mother.

THE ZOOLOGICAL GARDEN AT DUBLIN.

The Zoological Garden of Dublin belongs to The Royal Zoological Society of Ireland, founded in 1830. This society, which has for its object "to form a collection of living animals on the plan of the Zoological Society of London," comprises to-day (1906) 837 active members, 44 corresponding members, and 15 honorary members. It is administered by an elected council composed of 24 members, there being one president (the Rt. Hon. Jonathan Hogg), five vice-presidents, one secretary (Dr. R. F. Scharff), and one treasurer (Prof. A. F. Dixon). The council take a friendly breakfast together every Saturday morning, and I had the honor of assisting at one of these gatherings. It publishes annually for the general session of the society a very interesting report.

In 1905 the total receipts of the society amounted to £4,502 7s. 7d. Among the details of these receipts are the following:

	£	s.	d.
Admissions to garden	2,490	9	8
Animals sold	310	12	2
From restaurant	20	0	0
Elephant and pony tickets	63	10	0
Members' fees	662	15	0
Government grant	500	0	0

PARK AT TRING CASTLE. EMUS AT THE LEFT, KANGAROOS AT THE RIGHT.

INTERIOR VIEW OF THE LION HOUSE, DUBLIN.

The garden is administered, under the general direction of the secretary, by a superintendent, a former member of the constabulary, who lives in the garden and has under his orders ten keepers of animals, one night watchman, one gardener, one porter, and several young boys.

The expenditures of the garden in 1905 were as follows:

	£	s.	d.
Purchases of animals	194	6	3
Provisions for animals	804	13	6
Printing and stationery	51	0	10
Advertising	104	2	6
Building and repairs	607	14	9
Water rate	99	6	10
Salaries	1,099	14	0
Heating, lighting, etc	426	7	8
Total	3,387	6	4

The garden is open every day from 9 a. m. until sunset. If forms a part of the magnificent Phœnix Park, situated to the west of the city. It is elongated in shape, being some 1,600 feet in length by about 700 in width at the widest part, but the western half of the garden is occupied by a fine, large pond, bordered by broad, grassy slopes, covered with trees and shrubs. The remainder of the garden is made up of lawns, with some trees, but few flowers; there is a house for the superintendent, a restaurant, and a certain number of buildings, paddocks, aviaries, etc., in which live 711 animals, as follows:

	Number.	Species.
Mammals	215	90
Birds	408	113
Reptiles	15	7
Batrachians	4	2
Fish	69	12

Of this number, in 1905, 217 were presented and 120 purchased.

The primates are placed for the most part in a well-ventilated building whose general arrangement recalls, on a smaller scale, the monkey house of the garden at London. In a corner of this house the society has constructed, for the anthropoids, four large cages communicating with each other, two of which open toward the garden, from which they receive light and air abundantly; the two others face toward the interior of the house, from which they are really separated by a large glazed bay. These cages are raised 1 meter above the floor of the building, the space underneath forming a sort of cellar in which are contained the conduits for hot air; the cage floor is of wood impregnated with wax dissolved in petroleum; the partition walls are hollow so as to favor the circulation of the hot

air; the roof has wide windows, and the upper part of the partition separating the outside from the inside cages is itself of glass.

The Carnivora, about 60 in number, are scattered about in at least ten different buildings. The most important of these is the lion house, constructed in 1901, and called the Roberts House, after Lord Roberts, a former president of the society. This building, which cost but little more than 100,000 francs (pls. IV and V), was built and arranged according to data taken from the best examples in Europe and America. It consists of a main building inclosing a large hall 6 to 7 meters wide, covered with glass, with cages upon both sides. Each cage is 3.20 meters wide, 2.60 meters deep, and from 2 meters to 2.70 meters high; the upper part of the back wall is of red brick, the lower of white glazed brick; the lower part of the sides is of wood painted black, the upper part of sheet iron painted yellow; the ceiling and the front are of grill work; the floor, 1 meter above the ground, is of wood and slopes toward a large gutter that runs along in front of the cages. There are three or four large exterior cages and a lateral annex that conducts to the old lion house, now used as a nursery. It is in this latter house that have been conducted the important rearing of lions that have rendered the Dublin Garden so celebrated.

This rearing of lions commenced as far back as 1855, when the garden bought two animals from Natal that became the ancestors of a whole series of generations of Irish lions. In 1858, three years after their arrival in Dublin, this pair had a first litter of a single cub, the same year a second litter of 4 cubs, and the next year a third litter of 5. From this last litter came Old Girl, a lioness celebrated at Dublin, who lived for sixteen years in the garden and died there after having given birth to 55 cubs in 13 litters.

Up to 1885 there had been born in the garden 131 cubs from 4 lions and 9 lionesses; 21 of these cubs died, either at birth or while under maternal care; 13 died afterwards; 89 were sold, bringing £3,247 10s. (an average of £36 per capita); 5 were kept for breeding purposes, and the remaining 3 I have not been able to follow. Toward the end of this period another lioness, Queen, was born, who has given birth to 28 cubs.

From 1874 to 1878 there was an interruption in the births due to the fact that the male kept for reproduction had not yet reached puberty. Soon the births resumed their normal frequency up to 1893 or 1894. From this time for five or six years they fell off, and this could only be attributed to the weakness of the breeding animals. It had been the custom of the administration to keep for breeding only Irish males, always mating them with foreign females so as to avoid the possible disadvantages of consanguinity. It was thought best in this instance to completely renew the blood by purchasing

EXTERIOR VIEW OF THE LION HOUSE, DUBLIN.

a foreign male, so the council procured a magnificent Nubian lion which gave a new activity to the production and originated a new stock. Up to the present time there have been born at the garden 246 cubs, 127 of which were males, 112 females, and 7 in which the sex was not noted.

The breeding of other great *Felidæ* has not been as successful here. The Dublin Garden has not had during the last twenty years more than 6 or 7 tigers, one of which died from a nontuberculous skin affection. Nothing has resulted from the mating of these animals. The same be said as to the leopards, many of which have died here of cramps.

On the contrary, some Cape hunting dogs (*Lycaon pictus*), which died two years ago (1904), gave birth to young in the garden for four successive years (1896, 1897, 1898, 1899). This is all the more interesting because these animals rarely breed in captivity. As the mother had difficulty in nursing her offspring, a trial was made in 1897 of suckling them with a domestic dog. Under this regimen a young Lycaon reached the age of 5 or 6 months. The next year a young female was born and was kept in the garden in good health for five years.

When I visited the garden at Dublin there had just been built near the lion house a new structure for small carnivora, which were previously kept in the monkey house. It was a semicircular building, inclosing eighteen small cages, which by the removal of partitions could be transformed into nine large ones. These cages open externally upon a covered gallery for visitors, internally upon a parallel service passage. Each one is covered with glass and floored with wood treated with wax, the same as in the cages for anthropoids, and each has a small retiring compartment placed against one of the partitions 0.30 to 0.40 meter above the floor. The entrance to this can be closed by the keepers and is provided with a shelf upon which the animals may jump.

The house for *Herbivora*, situated a little farther away on the same side, was constructed in 1899. Its plan is the result of the observations and experience of a number of years and may be given as a model for similar constructions at the present time. It comprises a series of stables with a cement floor communicating with exterior paddocks which, like the stables themselves, are raised 0.30 meter above the surrounding ground.

The house for llamas and camels, constructed in 1897 and to which has since been added a glazed portion for giraffes, has seven or eight stables arranged in form of a cross, each having an exterior paddock. Two of these are specially arranged for females in gestation or for sick animals. The llamas and camels have bred there several times. * * *

I noted, among the most curious animals, a colony of Canadian porcupines (*Erethizon dorsatus*), which easily climb about upon the tree assigned to them, passing the whole day there; at evening these animals retreat to little houses placed around the trunk at some distance from the ground.

I noted that a certain number of birds elsewhere kept in inclosures or aviaries were left here in perfect liberty. It is not one of the least of the beauties of the garden to see egrets, pelicans, flamingoes, grebes, herons, swans, ducks, water hens, gulls, barnacle geese, etc., swimming about on the large pond and resting along its brink, or indeed to meet on the lawns or walks emus, rheas, peacocks, cranes, geese, etc., who come up to the visitor without fear and beg, sometimes with too much insistence, for morsels of bread.

THE ZOOLOGICAL GARDEN AT ANTWERP.

The Antwerp Garden is the only one of four Belgian zoological gardens founded during the last century that has survived. The one at Brussels was transformed in 1879 to become the Leopold Park, that at Ghent was closed, and that at Liège disappeared at the time of the International Exposition of 1905.

It was founded in 1843, and belongs to the Royal Society of Zoology of Antwerp (Limited), which has at the present time (April, 1906) 7,800 members. The affairs of the society are administered by a council of five members nominated and removable by the general assembly, from whose number they are chosen; there is a president (M. Albert Thys), a vice-president, a treasurer, and a secretary. This council meets at least once every two months. In conjunction with the director it has especial charge of everything relating to the sale, purchase, and exchange of objects belonging to the collections of the society. Its operations are also audited by a committee of five nominated and removable by the general assembly.

The receipts of the society for the years 1905–6 were as follows:

	Francs.
Membership fees	359, 789
Sales of tickets to strangers	187, 439
Sales of milk and butter	53, 918
Elephant and pony tickets	2, 917
Sales of manure	1, 650
Rent of restaurants	70, 762
Sale of animals	286, 144
Miscellaneous sources	30, 406
Total	993, 025

The garden is superintended by a director (at present Dr. Michel L'hoëst), nominated and removable by the general assembly by secret ballot, upon recommendations submitted by the council. This director, who has a salary of 12,000 francs and is allowed a house, has

the general superintendence of the garden and all the premises. He is charged with the preservation and maintenance of all the collections of the society and must especially see to the enforcement of the regulations of the garden and to the execution of all measures determined on by the council. He has under his orders all the employees of the establishment and recommends them to the council for appointment or dismissal.

The staff of the garden comprises about 100 employees, including the clerks in the offices, the gardeners, the keepers, and the different classes of workmen. The employees and their families have a right to the gratuitous services of a physician, who receives from the society an annual compensation of 2,000 francs. After thirty years of consecutive service they are allowed a retiring pension equivalent to half the salary received by them during the last year of their service, provided, however, that this pension shall never exceed 1,500 francs. In case of decease the pension may, in exceptional cases, be continued to the widow and orphans.

The society pays 1,200 francs per year to a veterinarian charged with making a daily visit to the garden.

The total paid for salaries in 1905–6 was 158,347 francs. Some of the other expenses were as follows:

	Francs.
Care and improvement of premises	46,236
Care of garden	4,715
Food of animals	126,261
Purchase of plants and shrubs	7,638
Heating, lighting, and water	28,345
Office expenses	6,957
Purchase of animals	315,371

The garden, situated in the middle of the city, covers an almost level surface about 10 hectares in extent. It has spacious lawns ornamented with beds of flowers, with shrubs and great trees, two large ponds for acquatic birds, and several small basins. Here and there statuary is placed—a monument to Darwin, the Prometheus group, a group of Indians returning from the chase, a horseman attacked by jaguars, etc.

Most of the large buildings are placed along the boundary line of the garden, and recall, by their different styles, the countries from which were derived the animals they shelter.

A large playground with gymnastic apparatus that, without charge, is at the disposal of children, fine cafés and restaurants, a winter garden, and a magnificent building called the Palais des Fêtes (which occupies about 4,500 square meters and cost about 1,300,000 francs) contribute to make the Antwerp garden a pleasant place whose elements, although a little incongruous, yet together form a strong attraction, much appreciated by Antwerp society.

At the time of my visit in October there were about 3,500 animals in the garden. The number is constantly varying by reason of the active traffic in animals that goes on there. In the month of August, for example, the aviaries and reserve cages of the garden often contain 50,000 to 60,000 small, exotic perching birds which are afterwards bought by dealers and amateurs.

The greater number of the animals are obtained from purchases made from captains of vessels or from sailors who come from the Indies, Africa, America, etc.; at Antwerp they are purchased directly by M. L'hoëst; at Marseilles purchases are made by Mr. Auguste Charbonnier, at Bordeaux by Mr. Marius Casartelli.

The monkeys, some 300 in number (a good many being in reserve cages, to which the public is not admitted), are installed in a large house, lighted from above and having on its southern side a large exterior cage of fine appearance. This house has a large central hall with five separate octagonal cages and a certain number of cages along the sides separated from the public by glass.

I noted two young orang-outangs and two young chimpanzees dressed in red or blue vests, but apparently not in as good health as those at Manchester or Bristol.[a]

There was also in the monkey house some 30 young *Cynocephalæ*, the only monkeys that go out into the exterior cage, and then only during summer; a few years ago some of the lemurs died of cold, apparently because they were left out too long in autumn.

The "palace" for large carnivora is an imposing structure of rather heavy appearance but very richly fitted up. At either end large entrances, with posts in the form of lion caryatides, give access to a large gallery having a double row of columns supporting a fine ceiling; in the middle of the western wall is a marble catch basin surrounded with green plants and the busts of former directors. Along the eastern wall are cages for the *Felidæ*, lighted from above and arranged like those in the lion house at Dublin; they communicate, but not freely, with exterior cages, three of which are large and in the form of rotundas. (These cages are washed out with plenty of water every day.) The lions and tigers kept here frequently breed, but not as regularly as at Dublin and Bristol; a pair of jaguars, however, has for the last six or seven years brought forth a young one each year.

The food of these animals is usually horse meat, but once a week they are given mutton or beef, which, it is said, fattens them better than an exclusive diet of horse meat. The large *Felidæ* fast every Saturday.

[a] The orangs here sleep on the floor upon a bed of hay; the chimpanzees upon a shelf raised above the surface of the floor.

For the bears the garden has happily abandoned the old plan of keeping them in deep, damp and badly lighted pits, such as seen almost everywhere. They are given fine, large, open-air cages, covered or surrounded by verdure.

The giraffes and dromedaries are placed, together with the zebras, wild asses, tapirs, and elephants, in an Egyptian temple whose majestic front and fine architectural lines of great purity of style make it one of the finest edifices in the garden. The exterior walls and peristyle of this building are covered with Egyptian paintings representing the inhabitants of tropical regions coming to offer to the city of Antwerp examples of the most characteristic animals of their countries.

The interior shows a large hall lighted from above and with lateral cages. The two giraffes only are shut off by glass partitions in order to give to their rooms the desired temperature. They have sometimes, but rarely, bred here, and the young are often affected with rickets, manifested by a chronic inflammation of the joints.

The house for hippopotami is a large isolated building amply lighted on the sides and above. It contains three large, interior tanks, 2.5 meters deep, which communicate freely behind with a stall having a cement floor. Each stall opens independently into an exterior paddock into which the animals are allowed to go during summer and in fine days during spring and autumn. In winter the water for the tanks is warmed to 15°. It is stagnant water, which does not appear to be renewed as often as it should, for when I was there it gave off an offensive odor. However, the animals seem to do well. A pair of hippopotami, brought to the garden in 1881, have bred with considerable regularity nearly every year since, bringing forth 13 young in seventeen years, 7 males and 6 females. Two of these died shortly after birth; the others have thriven very well. The male of this first pair died in 1904; the female is still living, but, as she seems to be no longer able to bear, the garden bought, in 1905, two young females to replace her. * * *

The buildings for the ruminants have generally exterior yards with a floor formed of a layer of sand resting on a bed of cinders, which appeared, however, to be very damp after days of rain. The exterior yards for the antelope house, placed in the middle of the building, are covered with glass.

The reindeer live on the average six years in the Antwerp Garden and give birth each year to two or three little ones. Their food is as follows:

Morning: One kilo of oats, crushed maize, barley and rye mixed, besides two handfuls of lichens.

Evening: One-half kilo dry white bread, besides two handfuls of lichens.

A great anteater and two echidnas live in the monkey house, the former having been there five years, the latter three years. They are given finely chopped meat and eggs beaten up in milk. The anteater is in a large glazed cage, 1 meter above the floor paved with porcelain tiles; he has only a board to sleep on. The echidnas are in a small octagonal cage having a zinc floor covered with fine sand; curled up in a corner, they seem to avoid the light.

The birds form the greater part of the number of animals in the garden, but there is not the fine ornithological display that I admired at London. Neither did I notice any indication of any wild species nesting in the garden. The greater part of the birds are, however, kept there merely for sale.

THE ZOOLOGICAL GARDEN AT ROTTERDAM.

The Zoological Garden at Rotterdam (Diergaarde) belongs to the Vereeniging Rotterdamsche Diergaarde, a limited society, whose object is thus defined by Article I of its statutes:

> The society, founded in 1857[a] under the name of Rotterdamsche Diergaarde, has for its object the advancement, by agreeable means, of our knowledge of zoology and botany.
>
> In order to accomplish this, collections of living animals and plants will be increased and maintained as far as the finances of the society will permit.
>
> A museum and a library will be added to the institution.
>
> The number of members is not limited.

This number amounted on December 31, 1906, to 5,484. The society is administered by a council of 25 members, of whom the president is now Mr. C. H. Van Dam. This council is itself composed of five committees; viz, of buildings, of animals, of plants (hothouses and gardens), of entertainments, of the library and museum.

The total receipts of the society in 1905 were 161,880.91 florins, of which there were—

	Florins.
Gate receipts	24,944.65
Sales of animals	7,550.00
Restaurant receipts	8,325.00
Sales of guides and postal cards	212.00

The society has established, as was proposed, a library and a museum. The library, superbly installed on the first floor of the administration building to the left of the principal entrance, contains numerous bound volumes and scientific periodicals. The museum, which occupies the entire first floor of the restaurant building, has two halls; one devoted to an ethnological collection derived from the Dutch colonies and from western Africa; the other devoted to birds

[a] The garden already existed in 1855 as a private menagerie.

EXTERIOR OF NEW MONKEY HOUSE, ROTTERDAM.

and to indigenous mammals as well as to a collection of mollusks and polyps derived for the most part from the Dutch colonies.

The garden, including the library and museum, is administered by Dr. J. Büttikofer, a naturalist to whom we owe the greater part of our knowledge of the fauna of Liberia. This director, appointed by the council, has quarters in the garden and receives a salary of 4,400 florins. He really directs the garden and disposes of the sum voted annually by the council for the general expenses of the establishment. Besides, he can appoint or remove the employees of the garden, except the chiefs, whose appointment or removal he can only recommend to the council.

The society has established a special fund for the medical care and pensions of its employees.

The garden is situated northwest of Rotterdam upon a marshy subsoil which in many places has given trouble as to foundations. Its area is about 13½ hectares. The general design of its shrubbery and flower beds is very pleasing. In certain localities distant perspectives are introduced which make one forget the city, essentially commercial in its character, that surrounds one on all sides; there are picturesque bridges spanning water courses, and ponds fed by the Diergaarde Singel, one of the numerous canals of Rotterdam; handsome walks conduct the visitor to lawns shaded with great trees, in which are nesting at liberty herons, ravens, and storks; well-kept beds of flowers and rocks covered with alpine plants break here and there the monotony of the landscape, and, in the large hothouses one may specially admire the *Victoria regia*, whose leaves cover the surface of a large basin, and the tree ferns, one of which is 9 meters high.

A large number of the animals in the garden are presented by colonial employees of the Government and by planters. The society has also an agent in Batavia, who buys directly from the natives.

On entering the garden by the main entrance the first building on the right is the monkey house (pl. VI). This edifice, which is the finest and best constructed of any that I have seen up to this time, was completed last year and cost 86,000 gulden ($36,000). It is 42 meters long, 14 meters wide, and 9.5 meters high; lies east and west, has a blank wall on the north, while along its southern side, ornamented with sculptured monkeys and pretty designs in enameled brick, is a series of exterior cages.

The principal entrance, situated at the western end, leads into a large hall (pl. VII) flanked on either side by the cages of the monkeys ornamented by clumps of green plants and by the spray of two fountains surrounded by flowers. This hall is divided into three parts by two arcades, marking the entrance to the service corridors, which I will mention further on.

The roof is of glass bricks, of the Falconnier system, with the exception of a ventilating roof that runs the whole length of the hall, so that the cages are much better lighted than the hall. The advantage of these glass bricks, which also cover the exterior cages, is that they are an excellent protection against too sudden cooling and against currents of air, while they let the light pass freely. They are hollow and the interior cavity, because of the high temperature at which they are molded (850°) presents an almost absolute vacuum. This system advantageously replaces that of double windows. A shallow groove around each brick makes it possible to lay it in a certain amount of cement, so that the system is united in a very solid manner. The large windows at either end of the hall and the movable frames of the ventilation roof are fitted with ordinary window glass.

There are 37 interior and 11 exterior cages for the monkeys; some of them are 6 meters in diameter; almost all the others have a superficial area of 4 square meters; they are protected from the public by an iron balustrade which supports a grillage 2 meters in height. The floor of the cages, raised 0.75 meter above that of the hall, is formed of a thin layer of concrete, and supports a tree upon which the animals may climb, the trunk of which is carefully set in a cast-iron tube. The walls are lined with ivory-white glazed bricks; all the corners are rounded. The side of the cage presented to the public is closed by a grillage whose meshes do not correspond with those of the exterior grillage, so that it is very difficult to throw bread or anything else to the animals; only the cages of the anthropoids are provided with vertical bars.

The back wall of each cage has at its upper part a recess lighted by a window which looks out above a service passage, and in this upper part there is, in the cages of the south side only, the passage by which the monkeys reach the exterior cages. At one end of this passage is a movable trapdoor that the monkeys can easily raise, at the other a sliding door that the keepers can shut or open from the service passage by means of a chain.

All the cages have a glazed interior roof set obliquely from the front backward, attached on one side to the common roof, on the other supported by the grill in front. Each cage communicates with the service passage (1 meter wide, 2 meters high) by a vertical panel, and in this panel is an opening for introducing food and a small window that lights the passage and permits an inspection of the cage. In the service passage there are a certain number of cocks for drinking water, hot water, and gas, and a gutter to take off the drip from washing the cages. From the southern passage similar access may be had to the exterior cages.

The system for heating and ventilating this house appeared to me particularly well conceived. I visited it in the morning accompa-

INTERIOR OF NEW MONKEY HOUSE, ROTTERDAM.

nied by Mr. Büttikofer, who with the greatest kindness furnished me with all the information that I wished. There were at that time 150 monkeys in the interior cages and the morning cleaning up was not yet finished; still there was no bad odor and the air seemed as agreeable as that of a conservatory.

The double problem that had to be solved in constructing this house was, first, to obtain in all the cages an equable and constant temperature of at least 20° even during the greatest cold; second, to establish an ample ventilation, without drafts, so as to reduce to a minimum the disagreeable odor which I have found in various degrees in most of the monkey houses that I have visited.

In order to realize these desiderata, Mr. Büttikofer resolved to seek inspiration, if not to copy exactly the systems of heating and ventilation used in the new monkey house of the zoological garden at New York. The furnace room and store of coal are placed in a large cellar under the eastern extremity of the building. The water, brought nearly to the boiling point, enters a system of tubes 300 meters long, is carried throughout the entire building and returns cooled to the furnace. Four large hot-water pipes are under the cages, two other smaller ones run along the exterior walls in the upper part of the cages, so that the air cooled by the exterior walls is sufficiently reheated and the monkeys have there quite warm places, where they like to remain.

The ventilation is intimately connected with the heating. The cold air enters freely into two large conduits that run under the floors of the cages throughout their length close by the hot-water pipes, escapes by orifices in the upper part of these conduits, becomes heated by contact with the hot-water pipes, and warms the floor of the cages; then passes into the central hall through registers placed in front of the cages. From the hall a large part of the air enters the cages through the grills, then rises toward openings in the roof of each cage near the exterior wall, by which it passes into a conduit that communicates with two evacuation pipes. In this way the air that has been used and vitiated in the cages is removed from the building and can not return to the public hall. This outlet for vitiated air is favored by the inclined, interior roof of each cage; this roof, indeed, heated on both surfaces does not cool the vitiated air and prevents it from falling back into the cage. A simple system of valves placed at the inlet for cold air and the outlet for heated air enables one to regulate the currents. Besides, the ventilating chimneys are so made that in case this automatic ventilation should prove to be insufficient electric ventilators could easily be installed.

The fact that most of the monkeys inhabit moist tropical forests, and therefore should have air with a certain degree of humidity, has not been forgotten. To accomplish this there have been placed in the

hot-air conduits shallow receptacles for water which by evaporating imparts the necessary humidity; the spray of the fountains in the central hall also assists. Besides, the floor of the central hall is washed and watered freely every evening. The floors and walls of the cages are cleaned every day and washed from time to time with cresoline.

The reptiles, batrachians, and fishes are placed in a house of recent construction (opened in May, 1906), which also excited our admiration. The walls of this house are in great part made of the Falconnier glass bricks, while the roof is of ground glass, so that light is diffused throughout the rooms, which are three in number, a central and two lateral ones.

The central hall (pl. VIII), which is first entered, is decorated with paintings and ornamented with great clumps of papyrus and cypress; in the middle, surrounded by a grill, is a basin of water (which may be warmed) with a central island having gradually sloping edges on which may bask the inhabitants of the basin—crocodiles from the Nile and from Java, caimans from the Mississippi, an enormous monitor lizard from Java, and several species of tortoises.

In the lateral rooms there are, in the center, large cages for boas and pythons; along the sides, against the Falconnier bricks, are numerous little cages, miniature conservatories, and aquariums of various sizes placed one against the other about 1 meter above the floor. Beneath these installations, separated from the public corridor by glazed brick, run the water pipes which afford heat during winter. The small cages are supplied with moss and green plants, and each has, in one corner, a little basin for water which may be filled or emptied by cocks accessible from below. These cages contain batrachians and lizards; a chameleon had just laid some eggs on the moss at the time I passed by.

A description of the Rotterdam Garden is not complete without a mention of the infirmary and the granary. The former serves not only as an infirmary but also as a quarantine for animals that arrive at the garden. Upon arrival they are placed in separate chambers, easy to heat and disinfect, under the charge of a skilled attendant. This isolation gives them an opportunity to rest after their journey and has also two other advantages: First, by keeping the animals for some time it assures that they were not affected with any contagious disease when they arrived; then it makes it possible to free them from internal and external parasites, which they might convey to the other animals.

The granary is particularly well conceived. Built after the designs of Mr. Büttikofer, it prevents wastage of grain and loss of time and permits the storekeeper to easily supervise the keepers who come for food for the animals. Each kind of grain is placed in a bin filled *from the story* above and containing the supply necessary for one

CENTRAL HALL IN THE REPTILE HOUSE, ROTTERDAM.

month. A simple mechanism in each bin prevents the grain being injured by pressure and assures its regular outflow. The discharge spouts are in the basement, in a room large enough to permit several keepers to get grain at the same time under the supervision of the storekeeper.

ZOOLOGICAL GARDEN AT THE HAGUE.

The Zoological Garden at The Hague belongs to the "Koninklijk Zoologisch-Botanisch Genootschap," a limited society founded November 1, 1862, for a period of twenty-nine years and eight months. In July, 1891, its duration was prolonged for a similar period.

The object of the society, as defined by Article I of its statutes, is "to contribute to instruction by establishing a collection of living plants and animals, a museum and a library."

It is administered by a board of nine persons appointed for three years by the members, one-third being renewed every year. The board chooses from its members a president, a vice-president, and a secretary. They meet at least once a month, and every five years appoint a director, who has the management of the garden and the collections. This director, at present Mr. L. J. Dobbelmann, has under his orders 5 keepers of animals, 6 gardeners, 5 workmen, and a dozen of temporary employees. In his last annual report (1905) I find the following data:

	Florins.
Total receipts	80,889
Members' fees	32,843
Gate receipts (85,085)	19,675
Food of animals	4,716
Expenses of the aquarium	149

The garden is situated to the east of the city and is only about 6 hectares in extent. It is surrounded by water, meadows, and beautiful trees, which set it off to great advantage. Its collection of living animals is not of great importance, comprising during last year only 140 mammals of 30 different species, 570 birds of 187 different species, and a certain number of fishes.

ZOOLOGICAL GARDEN AT AMSTERDAM.

The Zoological Garden at Amsterdam (Dierentuin or Artis) belongs to the Koninklijk Zoologisch Genootschap, "Natura artis magistra" (hence the name Artis by which the inhabitants of Amsterdam designate the garden).

The Royal Society of Zoology was founded in 1838, in consequence of a circular sent out to the inhabitants of Amsterdam by an amateur, Mr. G. F. Westermann. That circular commenced as follows:

"Natura artis magistra." Under this title a society has been founded having for its object the study of natural history in an attractive and agreeable manner,

both by a collection of animals as well as by a cabinet of stuffed specimens of the animal kingdom.

The cabinet of stuffed specimens, derived from the collection of Mr. R. Draak, was opened to the public in 1837. Since that time it has constantly increased, by gifts and purchases, thanks to an intelligent collaboration given by the Municipal University of Amsterdam. This part of the garden comprises to-day an ethnographical museum, collections of zoology and comparative anatomy, and a representation of the fauna of the Netherlands. The latter includes not only Dutch vertebrate animals, mollusks, and insects, but has also groups of indigenous birds, with their nests, eggs, and little ones, shown in their natural surroundings. There are also there a certain number of stereoscopic views of nests photographed from nature. The society has also at the garden a library containing a very rich collection of works on natural history.

The collection of living animals was commenced in 1839 by the purchase of a menagerie, then celebrated, belonging to C. Van Aken. It has increased normally since that time, especially by the installation of an aquarium, constructed on ground granted by the city under certain conditions, to which I will again refer.

The society has at present (1905) 5,000 members. Its affairs are administered by a council of nine members. Its receipts amounted in 1905–6 to 228,500 florins, among which were the following:

	Florins.
Members' fees	112,500
Entrance fees from strangers (159,759 persons)	76,000
Sale of living animals	2,100
Sale of guide books	2,250
Revenue from restaurant	12,125

The garden is controlled by the director of the society, Dr. C. Kerbert, who has the power of nominating and removing employees and of freely making all purchases except very large ones without reference to the council.

The society puts aside every year 5,000 florins as a reserve fund from which to pay pensions to aged or sick employees.

The total paid for salaries in 1905 was 56,750 florins. Among other expenses I noted:

	Florins.
Food for animals	30,500
Purchase of animals	10,000
Maintenance of buildings	8,000
Expense of gardening	1,500

The garden is situated to the east of the city and has an area of 10.1208 hectares (25 acres). It appears a little shut in by the houses that surround it; its lawns and garden plats are not sufficiently extensive; the water of its ponds is too black and odorous; its buildings are

old and the paintings which ornament their walls have so faded that some of them are almost invisible. However, independently of the scientific interest that it presents, the garden does not lack in charm, and certain verdurous nooks ornamented with statues are worthy of the finest zoological gardens.

I was not able to ascertain the total number of animals existing in the garden at the time of my visit (October, 1906). There were, apparently, about 500 mammals; the number of other animals is very variable.

In one house, heated to 15° C., there was an orang-outang in company with a macaque. These animals were kept in a large, isolated cage, surrounded by a corridor glazed externally which separated them from the public. The orang has lived in the garden for five years without ever having been sick. Its continual activity and the brightness of its eyes were in striking contrast with the slow movements and sad looks of the orangs that I had previously seen in other gardens. How amusing, too, were the antics and struggles of these two monkeys! As is always the case, it was the smallest and weakest that was the most aggressive. At a certain moment the macaque was seated at the entrance to the exterior corridor the door of which had been opened for me; he was watching attentively the movements which I made in mounting my camera. But he annoyed the orang who, remaining in the cage, wished also to see; after making several ineffectual efforts to push the macaque aside, the orang seized him by the tail and threw him back roughly. The macaque, furious, uttered piercing cries and threw himself on the orang, who paused for a moment, quite astonished at such violent anger; then, calm, without apparent haste, jumped from side to side of the cage, always avoiding the macaque, who became more and more furious. The keeper, fortunately, put an end to the struggle by calling to the two monkeys, who immediately obeyed him; he opened the door of the inner cage and the orang, with kindly countenance, posed graciously before my camera, which seemed to puzzle him a good deal. * * *

The bear house, placed opposite the lion house, dates from 1897. It is a fine semicircular structure. The circular cages contain brown or black bears of various species. The brown bears produce young, but do not rear them. The white bears are placed in a large central cage which has at the back a rocky construction with cavities into which the females may retire. They have young every year and, unlike the brown bears, rear them very well.

The aquarium, which is one of the curiosities of the garden, dates from 1877. In that year the municipality of Amsterdam, which had already created a university, gave to the Royal Society of Zoology a piece of land comprising 2,735 square meters, in the immediate vicinity of the garden, under the condition that the society

should use this ground for the erection of a large building to contain an aquarium, an amphitheater, a museum, and working laboratories for the professors and pupils at the university, all students of natural sciences to have free entry every morning to the garden, the library, and the museum. For some time past Prof. Max Weber, the curator of the collections, in conjunction with Doctor Kerbert, present director of the garden, has obtained a unification of the most satisfactory kind between the collections of the university and those of the society.

The ground donated by the city rested on a subsoil of quicksand, as indeed is the case with all Amsterdam. Therefore 1,740 piles were driven down, and three years afterwards a magnificent building was completed on that site.

The aquarium, which is the only part of it that is the subject of this report, was arranged according to the system of continuous circulation of W. Alford Lloyd, a system that was used for the first time on a large scale at Paris in 1861 for the aquarium of the Jardin d'Acclimatation in the Bois de Boulogne.

Under the floor are three great reservoirs, two of which contain 447,845 liters of sea water, the other 116,256 liters of fresh water. It is pumped up by two gas engines of 8 horsepower (one in reserve) at one end of these reservoirs; delivered into two great conduits of enameled iron (having cocks of ebonite) which have a small opening for aeration at their proximal end; it is then carried to the upper floors and runs the whole length of the building above the tanks. From each great conduit the water passes into rubber tubes, placed at suitable intervals, and the ends of these, fitted with glass tubes, are directly above the tanks. As the terminal orifice of each of these tubes is but a few millimeters in diameter, the jet of water that issues from it has sufficient force, after being aerated a second time, to carry down with it a current sufficiently strong to carry away the impurities voided by the fishes into the water of the tank; the largest of these matters, falling to the bottom, are removed each morning by the attendants by means of aspirating tubes.

The tanks, of variable dimensions, are twenty in number. Nine have a total capacity of 84,695 liters of sea water and eleven a total capacity of 61,155 liters of fresh water. The largest has a capacity of 40 cubic meters.

The service of these tanks is effected from two lateral corridors having glazed roofs, in which are found small aquariums for zoological study and thirteen reserve tanks, nine, for sea water, having a capacity of 13,171 liters, and four, for fresh water, of 9,095 liters.

The water leaves the tanks in which the animals live by a lateral orifice and falls into a common conduit that takes it back to the reservoirs in the basement at the end opposite to that from which it issued.

Before returning there, however, this water undergoes a series of successive filtrations; it first falls into a linen cloth suspended at the end of the conduit, then it passes through a wooden grating that supports the cloth and afterwards traverses a bed of sand and gravel.

All the tanks have sandy bottoms, and one may see how the natural colors of the soles, flounders, etc., harmonize with them. They are also provided with artificial rocks covered with aquatic plants that form a dark background and enable one to see the animals perfectly and observe their behavior. No description indeed can do justice to the effect produced by these great fishes swimming gracefully in the transparent water of an enormous tank 5 or 6 meters long lighted by a diffused light in which their pearly colors sparkle.

In the little room at the back are found on separate tables a certain number of small glass aquariums, some cubical, others cup-shaped, for small marine animals and others, the temperature of which is kept constant by means of a thermo-regulator constructed according to the system of Prof. Max Weber. These aquariums contain exotic fishes from the Dutch Indies, from South America, China, etc.

The Amsterdam garden has also a special installation which I previously saw attempted only at one other place, the Zoological Garden at London; that is an insectarium, which, commenced in 1898 and enlarged in 1899, is now confided to the care of Mr. Polak, a teacher at Amsterdam.

This insectarium is not at all like the farms for raising butterflies which I visited in England, but it resembled them in paying especial attention to the rearing of nocturnal moths which in Holland constitute 95 per cent of the Lepidoptera. It is composed of a certain number of small cages or glass cases resting upon boxes and arranged entirely around one of the rooms of the reptile house, decorated with palm trees and green plants, which give it the appearance of a little conservatory.

Each insect cage is formed of a glass case without cover, placed with its opening downward on a zinc box, the upper surface of which, pierced with holes and covered with sand or moss, supports wide-mouthed vessels containing fresh plants on which the caterpillars feed. The glass of the top of the system is often replaced by a grillage and supports little insect boxes containing dried specimens of the same species that are seen alive below.

RÉSUMÉ.

Since my journey was limited to the United Kingdom, Belgium, and the Netherlands, it is not possible to draw from it any conclusions regarding zoological gardens in general, but I will give here a sort of synthetic résumé of the princi

hoping later to present a work upon the utilization of such establishments, not only for theoretical and practical science, but also for the education of artists and the general instruction of the public.

From an administrative point of view the great zoological gardens fall into four categories:

First. Those of Great Britain are carried on by a superintendent under the effective direction of the secretary of the society to whom the property belongs.

Second. The garden at Antwerp is administered and carried on by the president of the society aided by the director of the garden.

Third. The garden at The Hague is administered and carried on by a director appointed every five years.

Fourth. The gardens at Rotterdam and Amsterdam are administered and carried on freely by a director under the annual control of a council of administration.

The last of these systems seems to me to be the one best calculated to give a sustained activity and a progressive improvement in the methods of caring for the animals. The third one, on the contrary, seems the least fruitful of good results.

The following table will enable one to form a general idea of the activity of the great zoological gardens which I visited during the latter part of the year 1905–6. I will merely remark that the resources of the societies are composed of fixed fees for the members, annual subscriptions, gate receipts, sale of living or dead animals, milk, eggs, guidebooks and postal cards, rent of restaurants or amusement halls, and finally gifts, either of animals or money.

While the zoological gardens at London and Amsterdam, and the aquariums at Plymouth, Port Erin, and St. Hélier have undertaken more or less important works in morphology, physiology, or taxonomy, and the resources of the first two of these institutions have also enabled them to publish scientific periodicals whose value I willingly recognize, yet not one of them has undertaken the work for which it would seem they were really established, that is to say, observations or experiments made patiently and for a long time on living animals to determine their habits, reproductions, and relations with their environment, in fact upon what we have a right to ask of zoologists—the study of experimental transformism.

I am not, indeed, the only one who has made reflections of this kind. Already, in 1889, Professor Ray-Lankester remarked that, since Darwin, no large progress had been made in the line of general zoology, and he regretted that zoological gardens had always been conducted as popular exhibitions. (*Encyclopædia Britannica*, Vol. XXIV, p. 817.)

If these gardens have not been used for the study of general zoology, it would seem that, unfortunately, they have not materially

Statistical data of large zoological gardens, 1905–6.

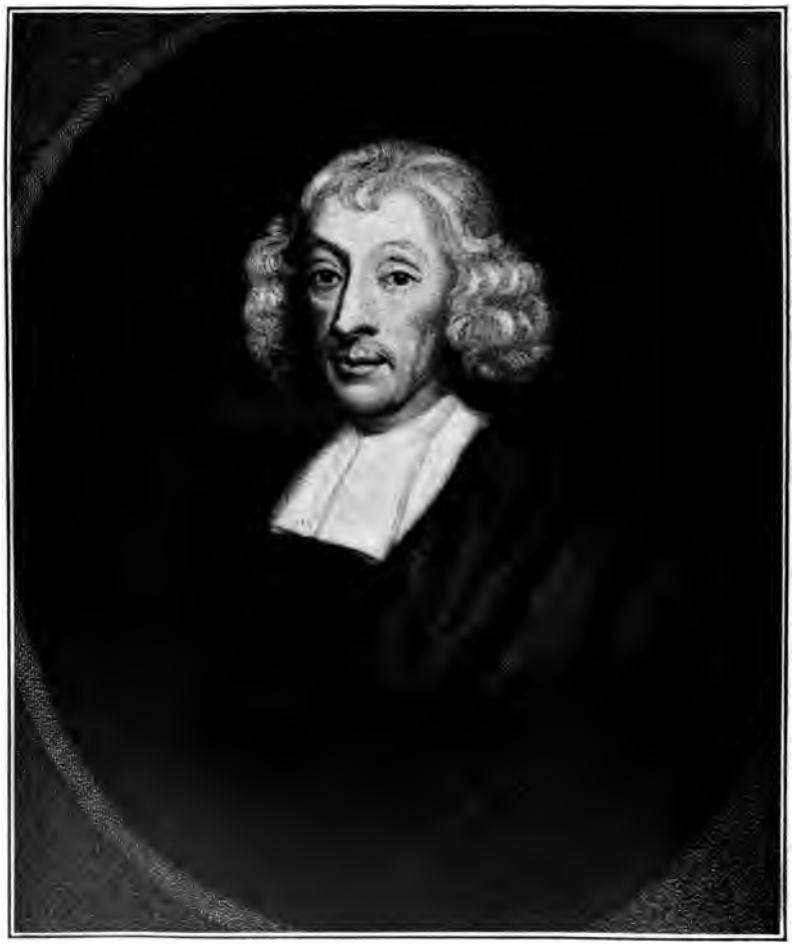
Location of garden.	Area.	Personnel.				Total number of animals.	Mammals.		Birds.		Reptiles and batrachians.		Fishes.	Total receipts.	Total expenditures.	Expenditures for food of animals.	Expenditures for purchase and transportation of animals.[a]
		Directing or scientific.	Subaltern (watchmen and employees).				Individuals.	Species.	Individuals.	Species.	Individuals.	Species.					
			For animals.	For grounds and hothouses.	Various.												
	Acres.																
Bristol	12	1 superintendent	7	13		[b]230	107	.....	110	.....	12	.....	.....	$34,724.62	$29,825.25	$2,676.38	$343.59
Dublin	.....	.....do	10	4		711	215	90	408	113	19	9	69	21,947.25	16,511.62	3,919.50	961.35
London	31	1 superintendent, 1 assistant, 1 prosector, 1 pathologist, 1 preparator.	60	16	31	2,913	689	.....	1,554	.....	560	.....	110	111,856.87	109,370.63	17,150.25	5,482.23
Amsterdam	25	1 director, 1 curator, 1 assistant, 1 preparator.	27	5	9	.....	500	.....	(c)	(c)	(c)	(c)	.....	93,570.75	45,045.00	12,489.75	4,095.00
Antwerp	25	1 director, 1 secretary, 1 naturalist, 1 inspector, 1 veterinarian.	38	13	36	3,500	(d)	(d)	(d)	(d)	(d)	(d)	.....	[b]175,500.00	[b]136,500.00	24,620.90	61,497.35
The Hague	15	1 director	5	6	5	[b]750	140	30	570	187	.....	.....	.....	33,123.87	(?)	1,931.09	(?)
Rotterdam	33¼	.....do	14	21	22	2,245	423	138	1,529	382	182	36	113	66,289.86	66,254.18	9,418.50	3,091.75

[a] In reality these sums are increased in many gardens by the proceeds of sales of animals born in the establishment.
[b] About. [c] Not ascertained. [d] Number very variable.

aided in the education and instruction of the people. Certain of their collections are doubtless fine, but the species of animals there shown are placed in a wholly artificial order, and the visitors seem to look only for the beasts that are most curious in form or color or most amusing in their movements.

Neither do the gardens serve to illustrate the zoological history of their countries, for we have not found anywhere, *reproducing in a constant manner*, representatives of the indigenous species or varieties that are at the present time threatened with extinction—the wild cattle and cats of Scotland and England, the red deer of Ireland, the cats and fowls of the Isle of Man, etc.

The zoological gardens do, however, offer at the present time a great advantage; that is, that they enable us to ascertain, by a comparison of their methods, the best means of preserving wild animals in captivity. This is by no means a slight matter, for this knowledge is evidently the primary condition without which it would not be possible to make any satisfactory observation or experiment.



JOHN RAY, 1627-1705.

SYSTEMATIC ZOOLOGY: ITS PROGRESS AND PURPOSE.[a]

By THEODORE GILL.

It is most fitting that in this year, when the scientific world is commemorating the natal centenaries of two naturalists who have been regarded as the chief systematists of their times, consideration should be given to the subject and object of their old pursuits. Carl Linné, whose bicentenary has been celebrated, was the man who first provided an elaborate code of laws for the nomenclature of all the kingdoms of nature and set an example to others by provision of concise and apt diagnoses of the groups and species he recognized. Louis Agassiz, who was born during the centenary year of Linné, gave a grand impulse to the study of nature in his adopted country, raised it in popular esteem, taught new methods of work, and directed to new lines of investigation.

Of all the students of nature from the time of Aristotle to the century of Linné, none requires present notice as a systematic zoologist except John Ray, who was the true scientific father of the Swede. Born in 1627, he flourished in England during the last quarter of the seventeenth century, and died only two years before the birth of Linné.

JOHN RAY.

It was long ago truly affirmed by Edwin Lankester that "Ray has been pronounced by Cuvier to be the first true systematist of the animal kingdom, and the principal guide of Linné in the department of nature."[b] He, indeed, made a pathway in the zoological field which Linné was glad to follow, and to some extent he anticipated the brightest thoughts of the great Swede. He, for example, in a dichotomous systematic table of the animal kingdom,[c] first combined the lunged fish-like aquatic and hairy quadruped viviparous animals in a special category (Vivipara) in contrast with all the other ver-

[a] Address before the Section of Systematic Zoology, Seventh International Zoological Congress, August 20, 1907.—Reprinted from Science, Oct. 18, 1907, with verbal modifications and additional notes.

[b] Lankester, Edwin, "The Correspondence of John Ray," 1848, p. 485.

[c] Ray, John, "Synopsis Methodica Animalium Quadrupedum et Serpentini Generis," 1693, p. 53.

tebrates, leaving to Linné only the privilege of giving a name to the class. He recognized a group of lung-bearing animals distinguished by a heart with a single ventricle, including quadrupeds and serpents, and thus appreciated better than Linné the class which the latter named Amphibia. He likewise gave the anatomical characters, based on the heart, blood, and lungs, which Linné used for his classes.[a]

THE BEGINNINGS OF SYSTEMATIC ZOOLOGY.

Systematic zoology is a vast subject, and any address devoted to it must necessarily be very partial. It need only be partial for such an assemblage of masters in zoology as I have the great honor to address, and I shall confine the present discourse to a review of some of the elements which have made systematic zoology what it now is. I will venture, too, to submit reasons why we may have to take a somewhat different view of the achievements of some men than did our early predecessors. If in doing so I may appear to be dogmatic, I entreat you in advance to insert all the "ifs" and "I thinks" and "perhaps" that you may deem to be necessary. For the present purpose, the work of two who exercised, each for a considerable time, a paramount influence on opinion and procedure deserves notice, especially because there has been much misapprehension respecting their benefits to natural science. The two were Carl Linné and Georges Cuvier; the one exercised dictatorship from the middle of the eighteenth century till some time after its close; the other was almost

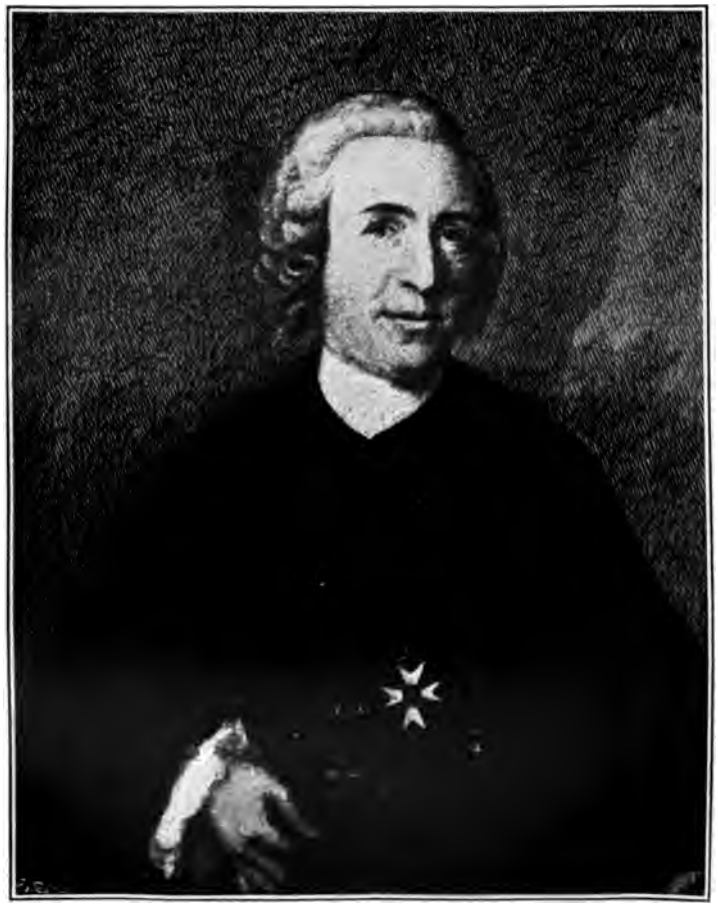
[a] The "Synopsis Methodica Animalium Quadrupedum et Serpentini Generis" of Ray is very scarce, and the account of his views given in various works misleading; therefore his arrangement of the Animal Kingdom, so far as the Vertebrates are involved, is here reproduced (from p. 53):

Animalium Tabula generalis.

Animalia sunt vel

- *Sanguinea*, eáque vel
  - *Pulmone respirantia*, corde ventriculis prædito,
    - *Duobus*
      - *Vivipara* [=MAMMALIA Linn.]
        - *Aquatica*; cetaceum genus.
        - *Terrestria*, Quadrupedia, vel, ut *Manati* etiam complectantur, pilosa. Animalia hujus generis amphibia terrestribus annumeramus.
      - *Ovipara*, Aves [=AVES Linn.]
    - *Unico*, Quadrupedia vivipara & Serpentes. [=AMPHIBIA pp. Linn.]
  - *Branchiis respirantia*, Pisces sanguinei præter Cetaceos omnes. [=PISCES and AMPHIBIA NANTES Linn.]
- *Exanguia*. [=INVERTEBRATA]

The arrangement of the Invertebrates is not better (nor worse) than that of Linné; that of the Vertebrates is better. Furthermore, Ray segregated the Vertebrates (as Sanguinea) from the Invertebrates (Exanguia), which wise arrangement Linné did not adopt.



CAROLUS LINNÆUS (CARL VON LINNÉ), 1707-1778.

equally dominant from the first quarter of the last century to well into the third quarter. No other men approached either of these two in influence on the work of contemporaries or successors. The evil features, as well as the good, were transmitted to and adopted by later authors. Therefore, a notice of those features may assist us to a correct judgment of the history of our subject, and may help to show why the disciples of the great Swede, as well as the great Frenchman, complicated many problems they investigated. Sufficient time has elapsed to enable us to judge knowingly and impartially.

CARL VON LINNÉ.

Linné needs no present eulogy, for this year his praises have resounded over the whole world. Born just two centuries ago (1707), he published the first edition of the "Systema Naturæ" in 1735, and his last (twelfth) in 1766. The various editions mark to some extent the steps of man's progress in the knowledge of nature during the time limited by the respective dates.

Linné's industry was great, his sympathies widespread, and his method in large part good. Compare the "Systema Naturæ" and other publications of Linné with works published by earlier authors, and the reason for the active appreciation and esteem which greeted his work will be obvious. The typographical dress and the clearness of expression left no doubt as to what the author meant, and enabled the student to readily grasp his intentions. His boldness in giving expression to new ideas insured success when they deserved it. Although Ray had already recognized four of the great groups or classes of vertebrates, he had not named two of them, and there were vernacular terms only for the birds and fishes. Linné, for the first time, applied names to the other groups, and admirable ones they were. Mammalia and Amphibia were the coinage of Linné and are still retained; Mammalia or mammals by all; Amphibia or amphibians by the majority for one of the classes now adopted.

A great advance, too—an inspiration of genius, indeed—was the segregation of the animals combined under the class of mammals. Popular prejudice was long universal and is still largely against the idea involved. Sacred writ and classical poetry were against it. It seemed quite unnatural to separate aquatic whales from the fishes which they resembled so much in form and associate them with terrestrial hairy quadrupeds. How difficult it was to accustom one's self to the idea is hard for naturalists of the present day to appreciate. Linné himself was not reconciled to the idea till 1758, although Ray had more than hinted at it over three-score years before. At last, however, in no uncertain terms, he promulgated it. It was a triumph

of science over popular impressions; of anatomical consideration over superficial views.

But mingled with the great benefactions were many views which long influenced naturalists, but which modern zoology has overthrown.

LINNÆAN CLASSES.

After the tentative arrangements published in the original first, second, and sixth editions of the "Systema," Linné thoroughly revised his work, and first consistently applied the binomial method of nomenclature to all species in the tenth edition, published in 1758. Six classes were admitted with equal rank, no category being recognized between the class and kingdom. The classes were the Mammalia or mammals, Aves or birds, Amphibia, Pisces, Insecta, and Vermes. The first four of these classes correspond mainly to the Aves and nameless groups of Ray.

During the Linnæan period of activity the invertebrates were little understood, and his treatment of that enormous host, referred to his two classes Insecta and Vermes, contrasts rather than compares with that at the present time. Naturally, the vertebrates were much better comprehended, and all such then known, with a single exception, were distributed among four classes just named, the Mammalia, Aves, Amphibia, and Pisces. The solitary exception of exclusion of a true vertebrate from its fellows was the reference of the genus *Myxine* to the Vermes, next to *Teredo*, the shipworm. The first two classes were adopted with the same limits they now have, but the Amphibia and Pisces were constituted in a truly remarkable manner. The class of Amphibia was a creation of Linné, and was simply contrasted with his Pisces by having a lung of some kind or other ("*pulmone arbitrario*"), while the Pisces have exposed branchiæ ("*branchiis externis*"). The Amphibia, thus defined, were made to include as orders: (1) Reptiles, or Reptilia, having feet; (2) Serpentes, footless, and (3) Nantes, having fins.

Under the Nantes were first grouped the lampreys, the selachians, the anglers (*Lophius*), and the sturgeons (*Acipenser*). In the twelfth edition were added *Cyclopterus*, *Balistes*, *Ostracion*, *Tetrodon*, *Diodon*, *Centriscus*, *Syngnathus*, and *Pegasus*. The Nantes were added to the Amphibia partly because of the assumption that the branchial pouches of the lampreys and the selachians were lungs and partly on the authority of Dr. Alexander Garden, of Charleston, S. C., who mistook the peculiar transversely expanded and partly double air-bladder of *Diodon* for a lung. With such errors of observation as a basis, Linné apparently assumed that all the associated genera also had lungs. Gmelin, in his edition of the "Systema Naturæ" (generally

called the thirteenth), corrected this error, and returned all the Nantes to the class of Pisces, thus reverting to the older view of Linné himself. The Pisces of Linné included only the genera left after the exclusion of those just named and also of *Myxine*, which last was referred to the class of Vermes between the leeches (*Hirudo*) and the shipworms (*Teredo*).

LINNÆAN GENERA.

The genera of Linné were intended and thought by him to be natural,[a] and natural groups some of the so-called genera were, but present opinion assigns to most of them a very different valuation from that given in the "System Naturæ." Some of the genera of Invertebrates were extremely comprehensive. For example, *Asterias* included all the members of the modern classes of Stelleroidea or Asteroidea and Ophiuroidea; *Echinus* was coequal with the Echinoidea; *Cancer*, *Scorpio*, *Aranea*, *Scolopendra*, and *Julus* were essentially coextensive with orders or even higher groups of the zoologists of the present time. Others were so heterogeneous that they can not be compared with modern groups. Thus *Holothuria*, in the last edition of the "Systema," was made to include four holothurians in the modern sense, a worm, a physaliid, and three tunicates; in other terms, the so-called genus included representatives of four different classes and even branches of the animal kingdom.

It has been stated by various writers that the genera of Linné were essentially coequal with the families of modern authors, but, as has been indicated, such is by no means the case. Other striking exceptions to the generalization may be shown.

Not a few of the genera of Vertebrates, although not of the superlative rank as several of the Invertebrates, were equivalent to orders of modern zoology; such were, in the main, *Simia*, *Testudo*, *Vespertilio*, and *Rana*. *Simia* included all the anthropoid Primates except man; *Vespertilio* was equivalent to the order Chiroptera less the genus *Noctilio; Testudo* was exactly equal to the order Testudinata or Chelonia; *Rana* to the order Salientia or Anura. A number of other genera of one or few species known to Linné were also of ordinal or subordinal value.

In striking contrast with the range of variation of such genera were others, of which several, well represented in northern waters, may be taken as examples. *Scorpæna* was distinguished simply because it had skinny tags on the head;[b] *Labrus* because it had free membranous extensions behind the dorsal spines;[c] and *Cobitis* be-

[a] Classis et ordo est sapientiæ, genus et species Naturæ opus.—Linn. Syst. Nat., I, 13.

[b] *Scorpæna.* Caput cirris adspersum.

[c] *Labrus.* Pinna dorsalis ramento post spinas notata.

cause it had the caudal peduncle of regular height[a] and scarcely constricted as usual in fishes. These characters are of such slight systematic importance that they have not been used in the diagnoses of the genera by modern ichthyologists. Further, use of them misled even Linné as well as his successors. Some of the consequences may be noticed.

The close affinity of the "Norway haddock" or Swedish Kungsfisk or Rödfisk (*Sebastes marinus*) to the typical *Scorpæna* was unperceived and that species referred to *Perca* and even confounded with a *Serranus*.

The typical *Labri* of the northern seas do, indeed, have filiform processes of the fin membrane behind the dorsal spines, but most of the species referred by Linné to *Labrus* do not, and among them is a common sunfish (*auritus* = *Lepomis auritus*) of America.

The genus *Cobitis* was made to include Cyprinodonts of the genera *Anableps* and *Fundulus*, and thus were associated fishes differentiated from the Loaches by characters of immeasurably more importance than the trivial one which was the sole cause of their juxtaposition.

Another conspicuous instance of a trivial character used as generic, and contrasting with very important differentials of species included under the same genus, is furnished by *Esox*. The essential Linnæan diagnostic character is the protrusion of the lower jaw.[b] Nine species were referred to the genus which represent no less than eight distinct and, mostly, widely separated families of modern systematists.[c] Several of the species do not have the prominent lower jaw. and one of them (*Lepisosteus osseus* of modern ichthyology) is especially distinguished by Linné himself on account of the shorter lower jaw.[d]

But the most marked cases of insignificance of characters used to differentiate by the side of those serving for combination are found in the class Amphibia.

The genus *Lacerta* is made to include all but one of the pedate Lizards, and the Crocodilians as well as the salamanders, but the "dragons," or Agamoid lizards with expansible ribs, are set apart in an independent genus.[e]

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[a] *Cobitis*. Corpus vix ad caudam angustatum.

[b] *Esox*. Mandibula inferior longior, punctata. Syst. Nat., '58; '66, 424.

[c] The species are (1) *Sphyræna* (Sphyrænidæ, (2) *osseus* (Lepisosteidæ), (3) *Vulpes* (Albulidæ), (4) *Synodus* (Synodontidæ), (5) *lucius* (Lucilidæ), (6) *belone* (Esocidæ), (7) *hepsetus* and (8) *brasiliensis* (Exocœtidæ), and (9) *gymnocephalus* (Chirocentridæ). Syst. Nat., '66, 513–517.

[d] Mandibula inferior brevior. Syst. Nat., '66, 516.

[e] *Lacerta*. "Corpus (Testa Alisve) nudum, caudatum" contrasting with *Draco*. "Corpus Alis volatile." Syst. Nat., '66, 349.

The genus *Coluber* was intended to embrace all the snakes, except those with a rattle or undivided abdominal and caudal scutes,[a] and hence the vipers and copperheads, so very closely related to the rattlesnakes, were combined with ordinary snakes instead of with their true relations.[b]

Many of the genera of Linné, in fact, were very incongruous, and the great Swede not infrequently failed to interpret and apply their characters in the allocation of species. A few cases furnished by common European or American fishes will illustrate what is meant.

Specimens of the common gunnell or butterfish were received by Linné at different times and once referred to his genus *Ophidion* and at another time to the genus *Blennius*, and the same species stands under both names in the last two editions of his "Systema."

The common toadfish of the Americans (*Opsanus tau*) was placed in the genus *Gadus* (*tau*) and a nearly related species of the Indian Ocean was referred to the genus *Cottus* (*grunniens*).

The common ten-pounder of the American coast served as the type and only species of the genus *Elops*, and also as a second species of the genus *Argentina*, although the characters given were in decided discord with those used for the latter genus, and in perfect harmony with those employed for the distinction of the former genus. Indeed, it might be properly assumed that the ascription of the *Argentina carolina* to *Argentina* was simply a matter of misplacement of a manuscript leaf, and such it may be even now considered, although the error is continued in the twelfth edition, having escaped the notice of Linné.

LINNÆAN NOMENCLATURE.

The code of nomenclature devised by Linné was in many respects admirable, but he did not provide sufficiently for the principle of priority in nomenclature. He set the example of changing a name given by himself or by others, when he thought a better one could be substituted; he also felt at liberty to change the intent of a genus. A few examples of many cases may illustrate.

In 1756 the name *Salacia* was given to the Portuguese man-of-war; in 1758 the name *Holothuria* was substituted; in 1766 the latter name was retained, but with a very different diagnosis, and for the first time four holothurians in the modern sense of the word were introduced.

In 1756 the names *Cenchris* and *Crotalophorus* were used for genera, two years later renamed *Boa* and *Crotalus*. In 1756 Artedi's

[a] *Coluber*. "Scuta abdominalia; squamæ caudales" contrasting with "*Crotalus*. Scuta abdominalia caudallaque cum crepitaculo" and "*Boa*. Scuta abdominalia caudallaque absque crepitaculo." Syst. Nat., '66, 349.

[b] As an example of *Coluber* a figure (tab. 3, fig. 2) of a snake with venom fangs was given.

name, *Catodon*, was retained for the sperm whale, and Artedi's *Physeter* mainly for the killers (*Orca*); but in 1758 *Physeter* was taken up for the sperm whale, for which it has been retained ever since, except by a very few naturalists.

In 1756 and 1758 *Ophidion* was used for an acanthopterygian jugular fish—the common northern butterfish, or gunnell, now generally called *Pholis*—but in 1766, under the guise of *Ophidium*, it was transferred to the Apodes and primarily used for the soft-finned (supposedly) apodal type, which is still known as the genus *Ophidium*.

In 1756 and 1758 *Trichechus* was used for the manatee alone, while the walrus was correctly associated with the seals, but in 1766 the very retrograde step was taken of associating the walrus with the manatee and retaining for the two the name *Trichechus*. Many naturalists persist to the present day in keeping the name for the walrus alone.

The example thus set by the master was naturally followed by his disciples. Many felt at liberty to change names and range of genera as they thought best and great confusion resulted, which has continued more or less down to this year of grace, 1907.

Many of the evils which have been the consequence could have been prevented or rectified if the British Association for the Advancement of Science had been logical in the code (often admirable) which it published in 1842. Instead, however, of accepting the edition of the "System Naturæ" (tenth) in which Linné first introduced the binomial nomenclature as the starting point, they preferred homage to an individual rather than truth to a principle, and insisted on the twelfth edition as the initial volume of zoological nomenclature.[a] The unfortunate consequences have been manifold. Such consequences are the natural outcome of illogical and ill-considered action and must always sooner or later follow. After these many years almost all naturalists have acceded to the adoption of the tenth edition.

[a] The addition of some genera and many species in the twelfth edition marked an advance in that respect of Linné's knowledge, but otherwise no firmer grasp of the materials on hand became manifest. On the contrary, one familiar with the species can scarcely fail to recognize an increase of a tendency to impatience in dealing with details and not seldom a snap judgment in the allocation of species in the genera. Indeed, under the circumstances, it would have been better if the last edition had never been published. No one who has not critically examined the Systema can have an idea of the extent of discrepancy between the generic diagnoses and contents, the duplication of species under different genera, the mistakes of synonymy, and other faults. It has been affirmed that Strickland, the chief formulator of the B. A. Code of 1842, had preferred the tenth edition, but was overruled by his less informed associates of the committee on nomenclature.

If the vertebrates were so much misunderstood by Linné, it may naturally be supposed that the invertebrates were equally or still less understood. Only one interesting case, however, can be referred to. In the ninth edition of the "Systema Naturæ" Linné had a monotypic genus *Salacia* (p. 79) with a species named *Physalis* which was evidently a *Physalia* as long understood. In the tenth edition the name *Holothuria* was substituted for *Salacia* and no holothurians in the modern sense were recognized. In the twelfth edition all the species of the former edition were retained, but the diagnosis was altered and four holothurians of recent authors were added, and thus animals of different subkingdoms or branches were confounded in the genus. Now, if we accept the tenth edition of the "Systema" as the starting of our nomenclature, obviously *Holothuria* can not be used as it has been for these many years, and it must be revived in place of *Physalia*, notwithstanding the laments of those who are distressed by such a change. The echinoderms now called holothurians must be renamed. We can imagine the clamor that will arise when some one attempts the change.[a]

Another fault of less moment—indeed a matter of taste chiefly—was committed by Linné. Very numerous names of plants and animals occur in the writings of various ancient authors and were mostly unidentifiable in the time of Linné. He drew upon this store with utter disregard of the consequences for names of new genera. Most of the ancient names can now be identified and associated with the species to which they were of old applied, and the incongruity of the old and new usage is striking. For example, *Dasypus*, a Greek name of the hare, was perverted to the armadillos; *Trochilus*, a name of an Egyptian plover, was misused for the humming birds; *Amia*, a name for a tunny, was transferred to the bowfin of North America. There was not the slightest justification for such perversion of the names in analogy or fitness of any kind; there was no real excuse for it. At the commencement of Linné's career (1737), the learned Professor Dillenius, of Oxford, strongly protested against such misusage for plant genera, but the sinner persisted in the practice till the end. Naturally his scholars and later nomenclators followed the bad example, and systematic zoology is consequently burdened with an immense number of the grossest and most misleading misapplications of ancient names revolting to the classicist and historian alike.

[a] After undisturbed possession of the name for nearly a century and a half, two naturalists independently, in the same month (August, 1907), challenged the right of the Holothurians to the name *Holothuria*, and contended that the typical holothurians of the moderns should be renamed—*Bohadschia* for the genus and *Bohadschiidæ* for the family. T. Gill published his remarks in Science for August 9 (p. 185) and F. Poche in the Zoologischer Anzeiger for August 20 (p. 106).

The influence of Linné continued to be felt and his system to be adopted until a new century had for some time run its course. Meanwhile, in France, a great zoologist was developing a new system which was published at length in 1817, and anew with many modifications a dozen years later (1829).

GEORGES LÉOPOLD CHRÉTIEN FRÉDÉRIC DAGOBERT CUVIER.

Georges Cuvier (born 1769) claimed[a] that before him naturalists, like Linné, distributed all the invertebrates among two classes.[b] In 1795 he published an account of memorable anatomical investigations of the invertebrates and ranged them all under six classes: Mollusks, crustaceans, insects, worms, echinoderms, and zoophytes. This was certainly a great improvement over previous systematic efforts, but from our standpoint crude in many respects. It was, however, necessarily crude, for naturalists had to learn how to look as well as to think.

Cuvier later essayed to do for the animal kingdom alone what Linné did for all the kingdoms of nature. So greatly had the number of known animals increased, however, that he did not attempt to give diagnoses of the species, but merely named them, mostly in footnotes. His superior knowledge of anatomy enabled him to institute great improvements in the system. He also first recognized the desirability of combining in major groups classes concerning which a number of general propositions could be postulated.

It was in 1812 that Cuvier presented to the Academy of Sciences[c] his celebrated memoir on a new association of the classes of the animal kingdom, proposing a special category which he called branch (embranchment), and marshaling the classes recognized by him under four primary groups: (1) the Vertebrates or Animaux vertébrés; (2) the Mollusks or Animaux mollusques; (3) the Articulates or Animaux articulés, and (4) the Radiates or Animaux rayonnés. These were adopted in the "Règne Animal." In the first (1817) edition, as in the second (1829–1830), nineteen classes were recognized, and in the latter too little consideration was given to the numerous propositions for the improvement of the system that had been suggested and urged meanwhile.

It has been generally assumed that Cuvier's work was fully up to the high mark of the times of publication, and for many years the classification which he gave was accepted by the majority of naturalists as the standard of right. To such extent was this the case that his classification of fishes and the families then defined was retained to at least the penultimate decade of the last century by the first

[a] Règne Animal, 1817, I, 61.

[b] Scopoli and Storr admitted more classes.

[c] Ann. Mus. Hist. Nat., Paris, 1812, 19, 73–84.

GEORGES CUVIER, 1769-1832.

ichthyologists of France. Nevertheless the work was quite backward in some respects and exercised a retardative influence in that the pre-eminent regard in which the great Frenchman was held and the proclivity to follow a leader kept many from paying any attention to superior work emanating from Cuvier's contemporaries.

It is by no means always the naturalist who enjoys the greatest reputation for the time being that anticipates future conclusions. A Frenchman who held a small place in the world's regard in comparison with Cuvier advanced far ahead of him in certain ideas. Henri Marie Ducrotay de Blainville (1777–1850) was the man. When Cuvier (1817) associated the marsupials in the same order as the true carnivores and the monotremes with the edentates, Blainville (1816) contrasted the marsupials and monotremes as Implacentals ("Didelphes") against the ordinary Placentals ("Monodelphes"). While later (1829) Cuvier still approximated the marsupials to the carnivores, but in a distinct order between the carnivores and the rodents, and still retained the monotremes as a tribe of the edentates, Blainville (1834) recognized the marsupials and monotremes as distinct subclasses of mammals and had proposed the names Monodelphes, Didelphes and Ornithodelphes, still largely used by the most advanced of modern theorologists.

Against the action of Cuvier in ranging all the hoofed mammals in two orders, the pachyderms (including the elephants) and the ruminants, may be cited the philosophical ideas of Blainville (1816), who combined the same in two very different orders, the Ongulogrades and the Gravigrades (elephants), and distributed the normal Ongulogrades under two groups, those with unpaired hoofs (Imparidigitates) and those with paired hoofs (Paridigitates), thus anticipating the classification of Owen and recent naturalists by very many years.[a]

Cuvier's treatment of the amphibia of Linné equally contrasted with Blainville's. As late as 1829 the great French naturalist still treated the batrachians as a mere order of reptiles of a single family, and the crocodilians as a simple family of Saurians. On the other hand, as early as 1816 Blainville had given subclass rank to the naked amphibians with four orders, and also ordinal rank to the crocodilians, and a little later (1822) he raised the subclasses to class rank. Still more, Blainville early (1816) recognized that the so-called naked serpents

[a] A more familiar instance of difference between Cuvier and Blainville is that involving the systematic relation of the aye-aye (*Cheiromys* or *Daubentonia*). Cuvier, to the end of his life, referred it to the Rodents and, in the last edition of the Règne Animal, interposed it between the Flying-Squirrels (*Pteromys*) and Marmots (*Arctomys*). Blainville, on the contrary, as early as 1816, associated it with the Lemurs, to which it is now universally conceded to be most nearly related. The evidence is very conclusive. Was Cuvier unable to appreciate its significance or was he too opinionated to recant a determination once formed?

were true amphibians and gave satisfactory reasons for his assumption, though to the last Cuvier (1829) considered them to be merely a family of the ophidians. As Blainville claimed, he based his classification on anatomical facts.[a]

A pupil of Blainville, Ferdinand L'Herminier of the island of Guadeloupe, at the instance and following the lead of his master (1827), undertook the comparative study of the sternal apparatus of birds and thereby discovered a key to the natural relationship of many types which anticipated by many years the views now current. For instance, L'Herminier first correctly appreciated the differences of the ostriches and penguins from other birds, the difference between the passerines and swifts, the homogeneity of the former, and the affinity of the humming birds and the swifts. Meanwhile Cuvier, like Linné, was content to accept as the basis for his primary classification of birds, superficial modifications of the bill and feet (toes and nails) which led to many unnatural associations as well as separations, but which nevertheless have been persisted in even to our own day by many ornithologists.

Now what could have been the underlying idea which hindered the foremost comparative anatomist of his age from the recognition of what are now considered to be elementary truths and what enabled Blainville to forge so far ahead? Cuvier manifestly allowed himself to be influenced by the sentiment prevalent in his time, that systematic zoology and comparative anatomy were different provinces. It may, indeed, seem strange to make the charge against the preeminent anatomist, that he failed because he neglected anatomy, but it must become evident to all who carefully analyze his zoological works that such neglect was his prime fault. He, in fact, treated zoology and anatomy as distinct disciplines, or, in other words, he acted on the principle that animals should be considered independently from two points of view, the superficial, for those facts easily observed, and the profound, or anatomical characters. Blainville, on the contrary, almost from the first, considered animals in their entirety and would estimate their relations by a view of the entire organization.[b] Yet

[a] "Ses bases sont anatomiques et surtout tirées de la consideration du crâne." Bull. Sci. Soc. Philom., 1816, p. 111.

[b] The comparison instituted between Cuvier and Blainville is more than just to the former. Cuvier was not only eight years older than Blainville but longer and better established in scientific circles; he had also more control of scientific material and laboratories; he must also have known the anatomical facts as well as Blainville. The difference between the two, therefore, resulted from the manner in which they used the facilities at hand and the intellectual powers they applied to the consideration of the problems involved. While sometimes Cuvier more nearly anticipated conclusions now adopted, Blainville *did so much* more frequently. If, then, modern biologists are right, the man *who approached* nearest to them must be regarded pro tanto as the superior.

HENRI DE BLAINVILLE, 1777-1850.

PIERRE LATREILLE, 1762-1833.

the sentiment then prevalent was reflected by one who enjoyed a high reputation for a time as a "philosophical zoologist"—William Swainson. In "A Treatise on the Geography and Classification of Animals" (1836, p. 173), the author complained that "Cuvier rested his distinctions * * * upon characters which, however good, are not always comprehensible, except to the anatomist. The utility of his system, for general use, is consequently much diminished, and it gives the student an impression (certainly an erroneous one) that the internal, and not the external, structure of an animal alone decides its place in nature." It was long before such a mischievous opinion was discarded.

Cuvier was regarded almost universally by his contemporaries, and long afterwards, in the words of his intellectual successor, Louis Agassiz, as "the greatest zoologist of all time."[a] In view of the facts already cited and innumerable others that could be added, however, the contemporary verdict must be somewhat modified. Cuvier was a very great man of most impressive personality, wide versatility, extraordinary industry, vast knowledge of zoological and anatomical details, an excellent historian, a useful critic, and of good judgment in affairs generally, but, although a greater all-round man, as a systematic zoologist he was not the equal of a couple of his French contemporaries, Blainville and Latreille. We have either to admit this conclusion or confess that our now universally admitted views are wrong. Nevertheless, Cuvier's work was of great importance, and he first brought to the aid of systematic zoology the new science of vertebrate paleontology.

CUVIER AND PALEONTOLOGY.

The animals, and especially the vertebrates, of past ages were practically unknown to the early zoologists, and when they had large collections, as did Volta of the fishes of Mount Bolca, they identified them with modern species, or, with Scheuchzer, might consider a giant salamander as a man witness of the deluge—"Homo diluvii testis!" It was not until Cuvier, with superior knowledge of skeletal details, examined numerous bones unearthed from the Tertiary beds about Paris, that the complete distinction of animals of ancient formations from living species was recognized. Then was afforded the first glimpse of extinct faunas destined to far outnumber the existing one, but so imperfect was the great paleontologist's foresight of what lay in store for the future that he enunciated a dogma which was long accepted as sacrosanct; he called it the law of correlation of structure.

[a] Agassiz, "Essay on Classification," p. 286.

A striking and even amusing example of its exposition and its failure I have previously drawn attention to.

Professor Huxley, in his excellent "Introduction to the Classification of Animals" (published in 1869), in his first chapter, "On Classification in General," concluded a consideration of Cuvier's law of the correlation of structure with the following paragraphs:

> Cuvier, the more servile of whose imitators are fond of citing his mistaken doctrines as to the nature of the methods of paleontology against the conclusions of logic and of common sense, has put this so strongly that I can not refrain from quoting his words.[a]
>
> But I doubt if anyone would have divined, if untaught by observation, that all ruminants have the foot cleft, and that they alone have it. I doubt if anyone would have divined that there are frontal horns only in this class; that those among them which have sharp canines for the most part lack horns.
>
> However, since these relations are constant, they must have some sufficient cause; but since we are ignorant of it, we must make good the defect of the theory by means of observation; it enables us to establish empirical laws, which become almost as certain as rational laws, when they rest on sufficiently repeated observations; so that now, whoso sees merely the print of a cleft [fourchu] foot may conclude that the animal which left this impression ruminated, and this conclusion is as certain as any other in physics or morals. This footprint alone, then, yields to him who observes it, the form of the teeth, the form of the jaws, the form of the vertebræ, the form of all the bones of the legs, of the thighs, of the shoulders, and of the pelvis of the animal which has passed by; it is a surer mark than all those of Zadig.

The first perusal of these remarks would occasion surprise to some and immediately induce a second, more careful reading to ascertain whether they had not been misunderstood. Men much inferior in capacity to Cuvier or Huxley may at once recall living exceptions to the positive statements as to the coordination of the "foot cleft" with the other characteristics specified. One of the most common of domesticated animals—the hog—may come up before the "mind's eye," if not the actual eye at the moment, to refute any such correlation as was claimed. Nevertheless, notwithstanding the fierce controversial literature centered on Huxley, I have never seen an allusion to the lapse. And yet everyone will admit that the hog has the "foot cleft" just as any ruminant, but the "form of the teeth" and the form of some vertebræ are quite different from those of the ruminants and, of course, the multiple stomach and adaptation for rumination do not exist in the hog. That any one mammalogist should make such a slip is not very surprising, but that a second equally learned should follow in his steps is a singular psychological curiosity. To make the case clearer to those not well acquainted with mammals, I may add that *because the feet are cleft in the same manner* in the hogs as in

[a] "Ossemens fossiles," ed. 4me, tome 1r, p. 184.

RICHARD OWEN, 1804-1892.

JOHANNES MÜLLER, 1801-1858.

the ruminants,[a] both groups have long been associated in the same order under the name Paridigitates or Artiodactyles, contrasting with another (comprising the tapirs, rhinoceerotids and horses) called Imparidigitates or Perissodactyles.[b]

I need scarcely add that the law of correlation applied by Cuvier to the structures of ruminants entirely fails in the case of many extinct mammals discovered since Cuvier's days. Zadig would have been completely nonplussed if he could have seen the imprint of an Agriochœrid, a Uintatheriid, a Menodontid, or a Chalicotheriid.

The value of this law was long insisted upon by many. Some of the best anatomists, as Blainville, protested against its universality, but one who ranked with Cuvier in skill and knowledge of anatomy, Richard Owen, long upheld Cuvier's view. "You may be aware," he wrote in 1843, "that M. De Blainville contends that the ground—viz, a single bone or articular facet of a bone—on which Cuvier deemed it possible to reconstruct the entire animal, is inadequate to that end. In this opinion I do not coincide."[c] The many mistakes Owen made in attempting to apply the principle proves how well Blainville's contrary opinion was justified.

The numberless remains of past animals, exhumed from the many formations which the animals themselves distinguished, have entailed constant revisions of systems resulting from clearer comprehension of the development of the animal kingdom. Such revision, too, must continue for many generations yet to come.

CUVIER AND ANATOMY.

The failure to sufficiently apply anatomy to systematic zoology was especially exemplified in the treatment of the fishes which absorbed so much of Cuvier's attention in later years. He, as well as his associate, gave accounts of the visceral anatomy and was led—often misled—to conclusions respecting relations by his dissections,

[a] The only essential difference between the feet of hogs and ordinary ruminants is of degree in the development of the lateral hooflets. There is every gradation among the Artiodactyles, recent and extinct, between forms having the lateral hoofs aborted and those with all developed and accumbent on the ground, as in the Hippopotamus.

[b] Huxley had previously, in 1856, in an article "On the method of Palæontology" (Annals and Magazine of Natural History, 2d series, vol. 18, p. 49), called attention to the oversight of Cuvier; he quoted, in French, the passage here rendered in English, and added: "I confess that, considering the Pig has a cloven foot, and does not ruminate, the last assertion appears to me to be a little strong. But my object is not to criticise Cuvier," etc. Apparently he had forgotten the facts, however, when he wrote the Introduction referred to.

[c] Owen, Amer. Journ. Sci. and Arts, XLV, 1843, 185.

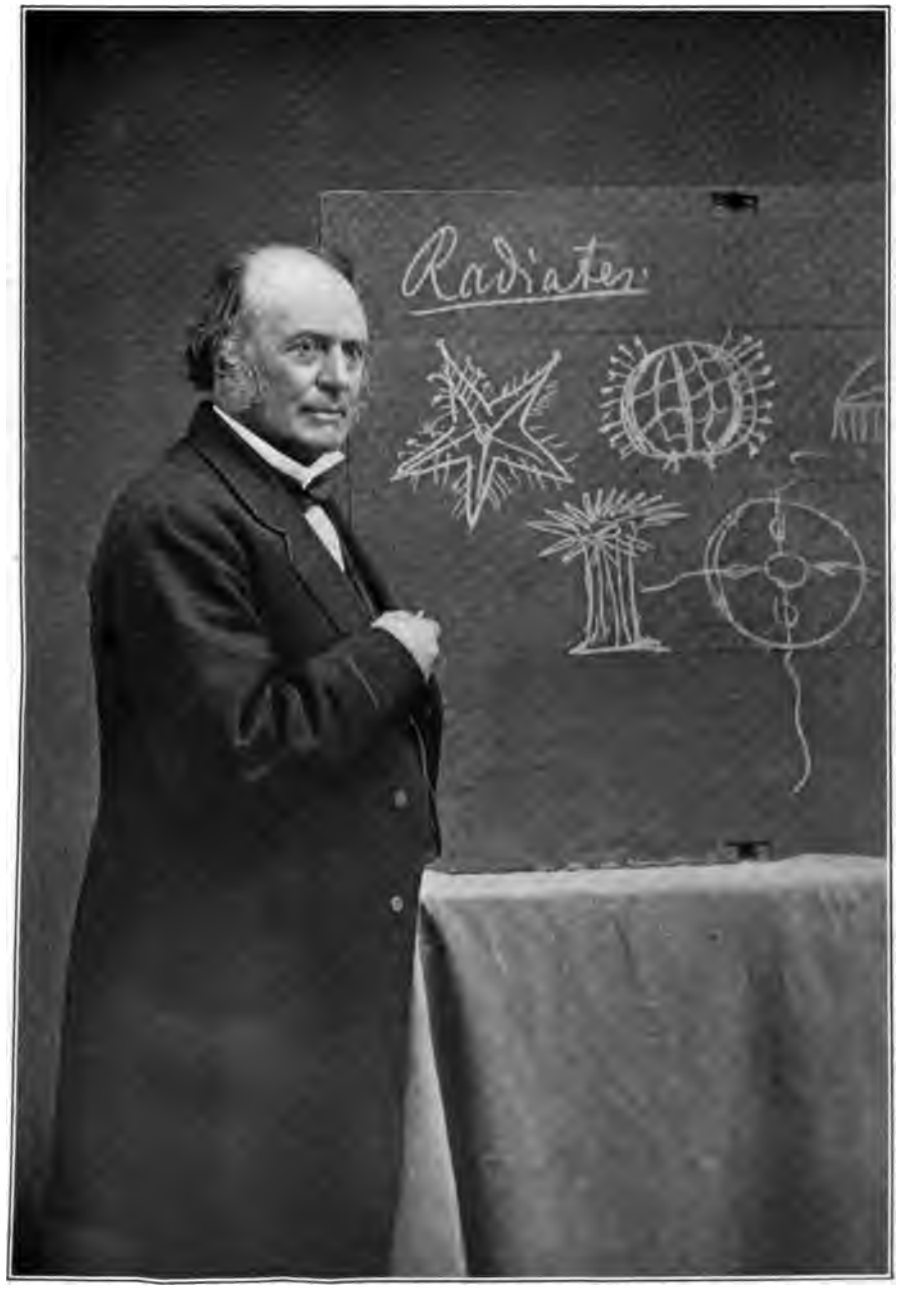
but he failed to receive enlightenment by examination of the numerous skeletons he had made. Those skeletons, pregnant with significance for the future, had no meaning for Cuvier; he never learned how to utilize them for the fishes as he did those of the mammals. His colleague and successor, Valenciennes, in the great "Histoire Naturelle des Poissons," was equally unappreciative of the importance of comparative osteology for comprehension of the mutual relations of the groups of fishes.

CUVIER'S SUCCESSORS.

The same defect in method or logic that characterized Cuvier's work was manifested by his great English successor in range of knowledge of comparative anatomy, Richard Owen. His families, for the most part, were the artificial assemblages brought together by zoologists on account of superficial characters and too often without rigorous attention to the applicability of the characters assigned. Much better was the work of the greatest naturalist of all, Johannes Müller, who advanced our knowledge of the systematic relations of all classes of vertebrates as well as invertebrates. But all were unable to free themselves from the incubus of the popular idea that all branchiferous vertebrates formed a unit to be compared with birds and mammals. Several propositions to segregate, as classes, Amphioxus and the chondropterygians had been made, and Louis Agassiz deserves the credit of claiming class value for the myzonts or marsipobranchs as well as the selachians. But it was left to Ernst Haeckel, a pupil of Müller, still happily living, to divest himself entirely of ancient prejudices and appreciate the interrelationship of the primary sections of the vertebrate branch. He for the first time (1866) set apart the amphioxids in a group opposed to all other vertebrates, then docked off the marsipobranchs from all the rest, and collected the classes generally recognized in essentially the same manner as is now prevalent. We may differ from Haeckel as to his classes of fishes and dipnoans, but his correctness in the action just noticed will be conceded by most, if not all, systematic zoologists to-day.

EMBRYOLOGY.

While Cuvier was still flourishing, a school of investigators into the developmental changes of the individual in different classes, and among them the vertebrates, was accumulating new material which should be of use to the systematic zoologist. Chief of these was Karl Ernst von Baer. In various memoirs (1826 et seq.) he subjected the major classification of animals to a critical review from an embryological point of view, recognized, with Cuvier, the existence of four distinct plans which he called types and characterized them in em-



LOUIS AGASSIZ, 1807-1873.

ERNST HAECKEL, 1834-

bryological terms—*Evolutio radiata*, *Evolutio contorta* (mollusks), *Evolutio gemina* (articulates) and *Evolutio bigemina* (vertebrates). The last were successively differentiated on account of the embryonic changes from the fishes to the mammals. "These Beiträge," Louis Agassiz justly affirmed, "and the papers in which Cuvier characterized for the first time the four great types of the animal kingdom, are among the most important contributions to general zoology ever published."

One of the most notable results, so far as systematic zoology was involved, was the deduction forced on Kowalevsky by his investigation of the embryology of tunicates, that those animals, long associated with acephalous mollusks, were really degenerate and specialized protovertebrates. This view early won general acceptance.

While embryology was very successfully used for the elucidation of systematic zoology its facts were often misunderstood and perverted. For instance, the cetaceans were regarded as low because they had a primitive fish-like form, although it must be obvious to all logical zoologists of the present time that they are derived from a quadruped stock; snakes have been also regarded as inferior in the scale because no legs were developed, although it would be now conceded by every instructed herpetologist that they are descendants of footed or lizard-like reptiles. *Ammocœtes* was considered as higher than *Petromyzon* "inasmuch as the division of the lips indicates a tendency toward a formation of a distinct upper and lower jaw," but we now know that *Ammocœtes* is the larval form of *Petromyzon*. Still more pertinent examples might be adduced without number for the inferior systematic grades, orders, families, genera, species, etc. The words high and low were used when generalized and specialized were really meant and those words, pregnant with mischief, often led their users astray as well as the students to which they were addressed.

PHILOSOPHICAL ZOOLOGY.

As knowledge of the various animal groups increased and countless new species were piling up, yearning arose to discover principles underlying the enormous mass of accumulating details, and the excogitations of various naturalists resulted in some curious speculation and expression in classificatory form. They called their outpourings philosophy or philosophical zoology, and philosophers they were called by others.

Some of the philosophers grouped animals according to supposed degrees of nervous sensibility;[a] some according to the relations of

[a] Lamarck (1812) contended for three categories of animals: (1) Apathetic animals and (2) sensitive animals among the invertebrates, and (3) intelligent animals, equivalent to the vertebrates.

parts to a center or an axis;[a] some under groups supposed to correspond with different systems of the body, as the alimentary, the vascular, the respiratory, the skeletal and the muscular,[b] and some would accord to each of the senses definite groups.[c]

Equally, if not more extravagant, views were entertained by many naturalists that creative power delighted in the symmetry of numbers and in circular arrangements.[d] It was contended that all groups of animals represented analogous groups in successively diminishing circles; that in a perfect system there were a definite number of subkingdoms, an equal number of classes in each subkingdom, of orders in each class, of suborders, of families, of genera, of subgenera, etc. Some maintained that three was the regnant number, others upheld four, others seven, but the most numerous and influential school con-

[a] Blainville (1816) proposed to divide the animal kingdom into three subkingdoms: (1) The Artiomorphes, having a bilateral form, (2) the Actinomorphes, having a radiate form, and (3) the Heteromorphes (mainly sponges and protozoans), having an irregular form.

[b] Oken (1802–1847) gave expression to his varying views in several differing classifications. In one scheme (El. Physiophilosophy, 1847, 511 et seq.) he claimed that there were five "circles" corresponding with the "animal systems:" (1) Intestinal animals (Protozoa and Radiates); (2) Vascular, sexual animals (Mollusks); (3) Respiratory, cutaneous animals (Articulates); (4) Sarcose animals (Vertebrates except mammals), and (5) Aistheseozoa, or animals "with all * * * organs of sense perfectly developed" (mammals).

[c] Oken maintained (1802–1847) "that the animal classes are virtually nothing else than a representation of the sense organs, and that they must be arranged in accordance with them. Thus, strictly speaking, there are only five animal classes: Dermatozoa (skin or touch animals), or the Invertebrata; Glossozoa (tongue animals), or the fishes * * *; Rhinozoa (nose animals), or the reptiles * * *; Otozoa (ear animals), or the birds; Ophthalmozoa (eye animals), or the Thricozoa (mammals) * * *. But since all vegetative systems are subordinate to the tegument or general sense of feeling, the Dermatozoa divide into just as many or corresponding divisions, which on account of the quantity of their contents, may be for the sake of convenience also termed classes."—Oken, El. Physiophilosophy, 1847, p. xi. For the many other assumptions on similar and divergent lines the reader must refer to the "Elements of Physiophilosophy" (1847).

[d] The style of argumentation used by the number-philosophers had long before been employed by Sizzi, a contemporary and antagonist of Galileo, who proved, to his own satisfaction, that there could be no more than seven planets. The inconsequentiality is remarkable. "There are seven windows given to animals in the domicile of the head, through which the air is admitted to the tabernacle of the body, to enlighten, to warm, and to nourish it; which windows are the principal parts of the microcosm, or little world—two nostrils, two eyes, two ears, and one mouth. So in the heavens, as in a macrocosm, or great world, there are two favorable stars, Jupiter and Venus; two unpropitious, Mars and Saturn; two luminaries, the Sun and the Moon; and Mercury alone, undecided and indifferent. From which, and from many other phenomena of nature, such as the seven metals, etc., which it were tedious to enumerate, we gather that the number of planets is necessarily seven." More follows of like tenor.

KARL VON BAER, 1792-1876.

JEAN LAMARCK, 1744-1829.

tended for five. Exactly what the philosophers thought they meant, or what strange visions they may have conjured up may never be known. But for a time (1822–1842) the school of quinarians, as they were called, claimed most of the naturalists of Britain. The most zealous of the school (William Swainson) was especially displeased with the developmental hypothesis of Lamarck and characterized the "speculations" of the great Frenchman "not merely as fanciful, but absolutely absurd."

But it was the much-contemned hypothesis of descent with modifications that was destined at last to relieve biological science of the wild and irrational speculations and classifications of the nature-philosophers, physiophilosophers, circularians, quinarians, trinarians, septenarians, and their like that flourished during the first half of the past century.

DEVELOPMENT THEORY.

Although there had been previous indications of belief that transmutation of species might have been a cause for the diversity of animal life, Jean Baptiste Pierre Antoine de Monet de Lamarck (1809) first framed a hypothesis that had a logical basis, although weakened by unproved postulates. In view of those weaknesses, it was easy to bring forth many facts that seemed to militate unanswerably against it, and such were well put forward by Cuvier; as the hypothesis, too, was very unpopular, it was for a long time stifled. In the meanwhile geological and paleontological investigation, comparative morphology, physiology, embryology, and zoogeography, as well as systematic zoology, were revealing innumerable facts that pointed all in the same direction and were only explicable collectively by the assumption that they were the result of original community of origin and subsequent deviation by gradual changes from time to time. The facts were at length collocated with extreme skill by Charles Darwin (1859) and a rational explanation of their evolution by means of natural selection made the new development theory acceptable to well-informed naturalists and logical thinkers generally.

SEQUENCE OF GROUPS.

It had been almost the universal custom from olden time, as well as during the Linnæan era, to commence the enumeration or catalogues of animals with the forms exhibiting most analogy with man and consequently the highest in the scale of organic nature. As long as species were assumed to be individually created this was perhaps the most natural course, and at least had the advantage of proceeding from the comparatively known to the almost unknown. A significant and noteworthy exception to this mode of procedure among

the old naturalists was afforded by Lamarck (1809 et seq.), the precursor in this respect, as well as in recognition of descent, of the modern school.

When it became generally recognized that there had been always a progression and development from antecedent forms, naturally there was a change in the manner of exposition of a series, and the lowest forms were taken as the initial ones and followed by those successively higher in the scale of beings. Even when old prejudices were administered to and the highest animals put first in a work, it was often done in a reversed series; that is, after the supposed natural ascensive series had been determined on, that series was simply reversed in order that the highest should be the first and the lowest the last. Many of our text-books of zoology still have this characteristic, but are being rapidly replaced by those exhibiting the phyletic series.

HISTOLOGY.

One of the most noteworthy modifications of systematic zoology was the fruit of histological research. In 1839 Theodor Schwann, incited by the brilliant results of Matthias Jacob Schleiden's researches (1838) in vegetal histology, and at the suggestion of Johannes Müller, undertook investigations which led him to consider that the animal frame was built up from innumerable cells variously modified to form the different systems and organs of which it is composed. Ultimately the animals thus developed were segregated by Ernst Haeckel, and the animal kingdom was limited to them, while the simple unicellular animals which had been already designated as Protozoa were associated with unicellular plants under the general term Protista. One of the prominent features of this idea was accepted by Thomas Henry Huxley (1874) with, however, the very important modification of retaining the old conception, the animal kingdom, and keeping the name Protozoa as the collective name of the unicellular animals while taking a suggested name of Haeckel's (Metazoa) for the multicellular animals.

GRADUAL DELIMITATION OF GENERA.

As has been already noted, the animal genera of Linné were mostly extremely comprehensive, answering, when natural groups, to families, superfamilies, and even orders or classes of modern naturalists. Such contrast, however, with others of the Linnæan genera, and when this fact became recognized and it was discovered that the large genera embraced types exhibiting many differences in detail, the latter were subdivided; early in the past century, at first owing especially to French and German naturalists, the subdivision of old genera on approximately present lines was commenced and applied at

CHARLES DARWIN, 1809-1882.

THEODOR SCHWANN, 1810-1882.

different times to various classes. It is noteworthy that in some instances the authors of the new genera quite abruptly changed their minds regarding the nature of such groups. For example, Lacépède, in 1798, in the closing lecture of his course at the Museum of Natural History, recognized only 51 genera of mammals, but a few months later (in 1799), in a "tableau," admitted and defined 84 genera.

It seems to be generally supposed that there has been an uninterrupted tendency among zoologists to refinement and increase of number of genera to the present time, but such is by no means the case. Half a century ago and more some ornithologists subdivided old genera and made new ones to an extent to which none of the present time is prepared to go. For example, Charles Bonaparte, Prince of Canino, required eleven genera of gulls to include those now congregated in one. About the same time, some herpetologists were equally radical. Leopold J. F. J. Fitzinger, in 1843, distributed species which are now combined by all in the genus *Anolis* among no less than fifteen genera. The genus *Bufo*, as now understood, was split by some herpetologists into a dozen or more. These are only samples of numberless analogous cases.

THE OLD AND THE NEW.

A comparison of systematic zoology at its dawn with that of the present time is rather a contrast of different themes.

The old naturalists believed that all species of animals were created as such by a divine fiat; the modern consider that all animals are derivatives from former ones and that their differences have been acquired during descent and development.

The Linnæans based their systems on superficial characteristics, and the moderns take into consideration the entire animal.

The early systematists assumed that characters drawn from structures or parts most useful to the animals were the best guides to the relationship of the animals; the latest ones have learned to distrust the evidential value of similarity of structures unaccompanied by similarity of all parts. The former were guided mainly by physiological characters; the latter take morphological ones.

The Linnæans confined their generalizations to few categories—genera, orders, classes; the moderns exhibit the manifold modifications and coordinations of all structural parts in many categories—genera, subfamilies, families, superfamilies and various higher groups.

The old naturalists believed more or less in the existence of a regular chain of beings from high to low; the new ones recognize the boundless ramifications of all animal stocks.

The elders assumed certain forms as highest and ranged their series from high to low; the sons commence their series with the most generalized types and progress from the generalized to the more specialized.

PROSPECTS AND NEEDS.

In numerous old systematic and descriptive works—but in many cases not very old—the skeleton and other anatomical details were noticed in connection with the species described, but not seldom some of those details, if rightly interpreted, would be in contravention of the classification adopted. In fact, the anatomy was to all intents and purposes treated as an offering of curious but useless information. Such conceptions, happily, are mainly—but not entirely—of the past, and we may live to welcome the day when every animal will be treated as whole. Systematic zoology will then be regarded as the expression of our knowledge of the entire structure and as an attempted equation of the results obtained by investigations of all kinds. In fact, systematic zoology is simply an attempt to estimate the relative importance of all structural details and to correlate them so that their relative values shall become most evident. It is the scientific outcome of all anatomical or morphological knowledge and the aim is to arrange the animal groups in such a manner as to show best their genetic relations and the successive steps of divergence from more or less generalized stocks.

One consummation devoutly to be wished for is general acceptance of a standard for comparison and the use of terms with as nearly equal values as the circumstances permit. There is a great difference in the use of taxonomic names for the different classes of the animal kingdom. The difference is especially great between usage for the birds and that for the fishes. For the former class, genera, families and orders are based on characters of a very trivial kind. For example, the family of Turdidæ, or thrushes, relieved of formal verbiage, has been distinguished from neighboring families solely because the young have spots on the breast, but even this distinction is now known to fail in some instances. Extremely few, if any, of the families of oscine birds are based on characters of a kind which would be regarded as of family value in other classes of vertebrates. On the other hand, many of the families and genera of fishes are made by some excellent authorities to include types separated by striking peculiarities of the skeleton as well as the exterior. The mammals are a class whose treatment has been mostly intermediate between that for the birds and that for the fishes. Its divisions, inferior as well as comprehensive, have been founded on anatomical characters to a greater extent than for any other class. Its students are numer-

THOMAS HENRY HUXLEY, 1825-1895.

ous and qualified. Mammalogy might therefore well be accepted as a standard for taxonomy, and the groups adopted for it be imitated as nearly as the differing conditions will admit. The families of birds would then be much reduced in number and those of fishes increased. All the active herpetologists and ichthyologists of the United States have subordinated their own beliefs and ideas as to what would have been most desirable, to a greater or less extent, to approximate the desirable reduction of the terms admitted by them to a standard uniform with that adopted by mammalogists. If others would likewise sacrifice their own predilections, the lamentable inequality of usage now prevalent would be much less; such congruity would be to the great advantage of comparative taxonomy.

In these days of extreme specialization one of the greatest needs in our universities is a professor of systematic zoology with whom conference may be held as to the propriety of any systematic modification resulting from special investigation of the anatomy of any organ or part, or of any group of animals. Such conference might prevent the publication of many propositions due to exclusive consideration of an isolated subject. Perhaps the designation of systematic morphology might better indicate the nature of the suggested course. The consummation, however, it must be admitted, is more desirable than probable.

I have intentionally refrained from any consideration of the work of living zoologists. If I had undertaken this, the task of selection would have been very difficult, and at any rate the time demanded for proper consideration would have been much more than that requisite for the reminder of past discoveries. The progress of systematic zoology during recent years has been in accelerated ratio, and not a few of those whose achievements have helped to put zoology at its present level are in Boston to-day. It is from the summit of the elevation they have enabled us to reach that we look back to the deeds of old masters and can determine, better than their contemporaries or immediate successors, their relative merits.

[NOTE.—The name "Linné" has been used because it was the one that the author assumed in the last (12th) edition of his great work. The title page has "CAROLI A LINNÉ, * * * Systema Naturæ," etc. After he was ennobled (1761) he dropped the Latin form and resumed the vernacular with the addition of *a* or *von*.]

41780—08——34

THE GENEALOGICAL HISTORY OF THE MARINE MAMMALS.[a]

By Prof. O. ABEL.

The old Norwegian "King's Mirror" of the thirteenth century enumerates a series of whales of commercial importance, among which we can recognize with certainty no less than thirteen kinds. While it is true that in this work correct observations are mingled with erroneous traditions, it is, nevertheless, one of the most valuable natural history documents of the Middle Ages, unhampered by prejudices and the burden of antiquated learning.

How greatly has our knowledge of marine mammals increased since that time, and how much have our views regarding them changed! Knowledge in this field has increased extraordinarily, especially during the second half of the last century. Although we have brought it to so great perfection compared with the King's Mirror, nevertheless, we still meet to-day with false ideas regarding marine mammals and their origin. Step by step we have brought ourselves to perceive that the ancestors of the whales, of the sea-cows, and of the seals are to be sought among land mammals, from which the different branches have been adapted independently for an aquatic life, and have developed separately.

We have approached nearer the solution of the problem of the origin of marine mammals in different ways. The first was through the investigation of embryos, for the purpose of finding ancient characters inherited from ancestors. The second way was by seeking through comparison of the organs of adult animals to reach conclusions regarding their relationship and derivation.

The direct evidence of the ancestors of living animals in the geological strata will, however, always be of decisive significance. The discoveries made in this field in late years have been so unexpected that the time seems favorable for rendering the present state of our investigations accessible to a larger circle of readers.

As a preliminary, we shall make a brief survey of living marine mammals, and afterwards consider their history more in detail.

[a] Translated, by permission, from "Meereskunde," Berlin, Jahrgang I, 1907, Heft 4.

I. Living Marine Mammals.

1. WHALES.

A. WHALEBONE WHALES.

The whalebone whales are not only the giants among living animals, but without doubt also the largest marine animals that have ever lived. No marine animal of the past has reached the length of the northern blue whale (or sulphurbottom, *Balænoptera musculus* L.), which attains 25 to 30 meters (82¼ to 98½ feet). (Fig. 1.)

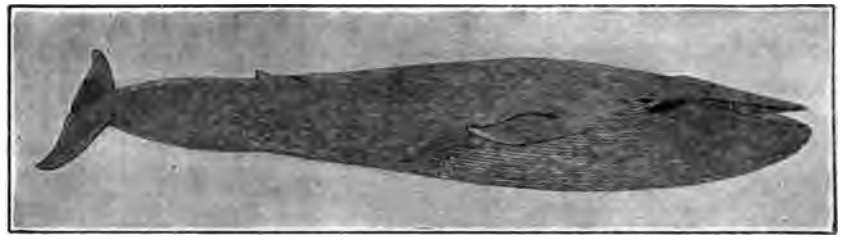


FIG. 1.—Blue whale, or Sulphurbottom (Balænoptera musculus L.). Length reaches 30 meters (98½ feet). After F. W. True.

First family, right whales.—The best known representative of this family is the Greenland whale (Arctic right whale, or bowhead), *Balæna mysticetus* L. Among the most remarkable characters of this clumsy animal, which reaches a length of 20 meters (65½ feet), is the enormous head, which alone occupies one-third to two-fifths of the total length. The flippers are short, broad, and five-fingered. The whalebone is very long and may reach the

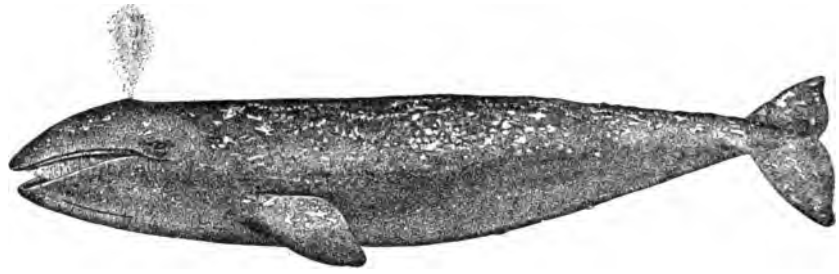


FIG. 2.—California Gray whale (Rhachianectes glaucus Cope). Length reaches 15 meters (49¼ feet). After C. M. Scammon.

extraordinary length of 15 feet in old animals. The belly is entirely smooth, and there is no fin on the back.

Second family, gray whales.—This family is represented only by the California gray whale (*Rhachianectes glaucus* Cope), which occupies a peculiar intermediate position between the right whales and the finbacks, or rorquals. It is nearly as long as the bowhead, but the body is more slender and the head is small. (Fig. 2.) The

pectoral fin, or flipper, is long and narrow, and has only four fingers. There are but two furrows on the underside of the body.

Third family, rorquals (finbacks and humpbacks).—To this group belong the gigantic blue whale, or sulphurbottom, previously mentioned (fig. 1); the humpback (*Megaptera nodosa* Bonn.), 17 meters (55¾ feet) long (fig. 3); the common finback (*Balænoptera physalus* L.), which has a length of about 23 meters (75½ feet); and the little piked whale (*Balænoptera acuto-rostrata* Lac.), which is only 9 or 10 meters (29½ to 32¾ feet) long.

The humpback (fig. 3) reminds one of the bowhead, on account of its turgid body, but differs from the latter both as regards its flipper, or pectoral fin, which is long, narrow and four-fingered, and measures almost one-third the total length of the body, and also on account of the presence of a small dorsal fin and of numerous furrows in the belly.

FIG. 3.—Humpback (Megaptera nodosa Bonn.). Length reaches 17 meters (55¾ feet). After F. W. True. The skin is covered with numerous parasites, in the form of closely clinging barnacles.

The sulphurbottom, common finback, and little piked whale are much more slender than the humpback, and have decidedly shorter flippers. The hand of the finbacks and humpbacks is four-fingered, owing to the disappearance of the middle finger.

The cervical vertebræ are separate in the finbacks, humpbacks and gray whale, but in the right whales are fused together, forming a compact, immovable mass.

B. TOOTHED WHALES.

The second group of living cetaceans is distinguished from the edentulous whalebone whales by the possession of teeth. In the whalebone whales there as many as 51 denticles in each jaw, but only in the early stages of embryonic life. They disappear long before the birth of the animal.

No toothed whale reaches the size of the sulphurbottom, but the male sperm whale (*Physeter macrocephalus* L.) is 18 meters (59 feet) long. The female is only half as long. The lower jaw of the sperm

whale (fig. 20) contains large, conical teeth, about 25 on each side, while the upper jaw (both maxillæ and premaxillæ) is toothless.

The sperm whales are allied to the beaked whales, which are represented by the bottle-nosed whale, *Hyperoödon*. This whale is at least 10 meters (32¾ feet) long, and is remarkable from the fact that it has only one, or at most two, pairs of teeth, in the front of the lower jaw. All the other teeth have disappeared, or are represented only by minute, stunted denticles in the gums, which are never cut.

The third family of toothed whales embraces two small river dolphins, one of which (*Pontoporia*, or *Stenodelphis*) (fig. 4) lives at

FIG. 4.

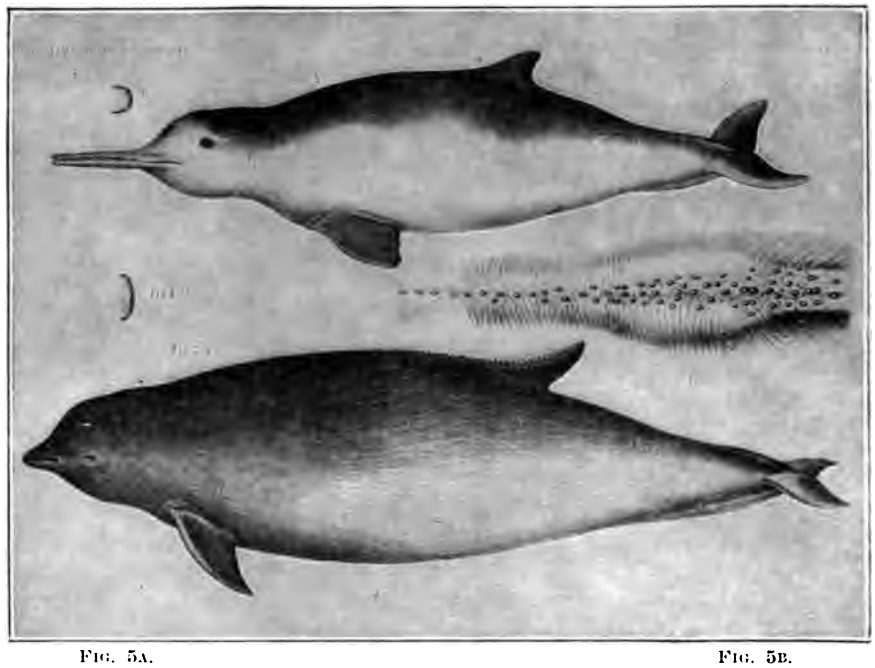


FIG. 5A. FIG. 5B.

FIG. 4.—River dolphin (Pontoporia or Stenodelphis blainvillei Gervais) from the mouth of the Rio de la Plata. About ½ natural size.

FIG. 5A.—Harbor porpoise (Phocæna spinipinnis Burmeister) from the Argentine coast. About ⅛ natural size.

FIG. 5B.—View of the dorsal fin of the same animal from above. In the divisions of the skin (Hautfeldern) are seen bony protuberances, which are the remains of the extensive dermal armor in the ancestors of this animal. About ⅓ natural size. After H. Burmeister.

the mouth of the Rio de la Plata, and the second (*Inia*) in the Amazon. It comprises also the white whale, or beluga (*Delphinapterus*), which reaches a length of 4 or 5 meters (13 to 16½ feet), and the narwhal.[a]

The enormous tusk of the male narwhal, which reaches a length of 3 meters, was looked upon in earlier ages as a miraculously powerful,

[a] The white whale and the narwhal are usually placed in the family Delphinidæ, or the true dolphins, but in a separate subfamily.—F. W. T.

though costly, medicine, and was universally considered to be the horn of the fabulous unicorn. In 1749 Leibniz gave a highly fantastic picture of it in his "Protogæa."

To the great group of dolphins belongs the harbor porpoise (*Phocæna*), which is abundant in almost all (northern) seas. This small dolphin, *P. phocæna*, which is only 1½ meters (5 feet) long, is noteworthy on account of the fact that small bony tubercles are to be found on the front margin of the dorsal fin and flippers, which tubercles are remnants of the dermal armor borne by its ancestors. The harbor porpoise often ascends streams a long distance, and has frequently been met with in the Elbe, Schelde, Thames, and Seine. Numerous genera and species of dolphins are recognized, as this family includes a great variety of forms. The killer whale (*Orcinus*) and the blackfish (*Globiocephalus*) belong to this family, as well as the common dolphin (*Delphinus delphis*), which was known to the ancients and is common in all seas.

The peculiar Ganges dolphin (*Platanista*), which lives in the great rivers of India, stands quite by itself. This dolphin is entirely blind, due, probably, to its living continuously in turbid waters. The eyes are only as large as peas, and have no lenses. The beak of this dolphin reminds one forcibly of the jaws of the gavial, or Ganges crocodile.

We shall now endeavor to summarize the common habits of the whales. They live exclusively in the water. No whale is fashioned to move on land. Progression takes place only through the powerful turning about of the great caudal fin, with its flukes, which acts like the screw at the stern of a ship.[a] The body is more or less fusiform, and the swiftest swimmers have a high dorsal fin, as well as a pointed snout, which cuts the waves like the prow of a ship. The arms and hands have been transformed into flippers, which serve as a steering apparatus. Since the work of propelling the body falls on the caudal fin, or flukes, the hind limbs have become superfluous, and have been reduced to rudiments which lie deep in the soft parts. (Figs. 25 and 26.) The pelvis has lost its connection with the vertebral column, and in the dolphins consists of a very small, slender rod of bone. In the bowhead, in addition to a larger remnant of the femur, a smaller remnant of the tibia is present. (Fig. 25, T.)

The dentition is adapted to environmental conditions in a remarkable manner. As the food is swallowed whole, the teeth have only the function of fangs to seize and hold the prey.

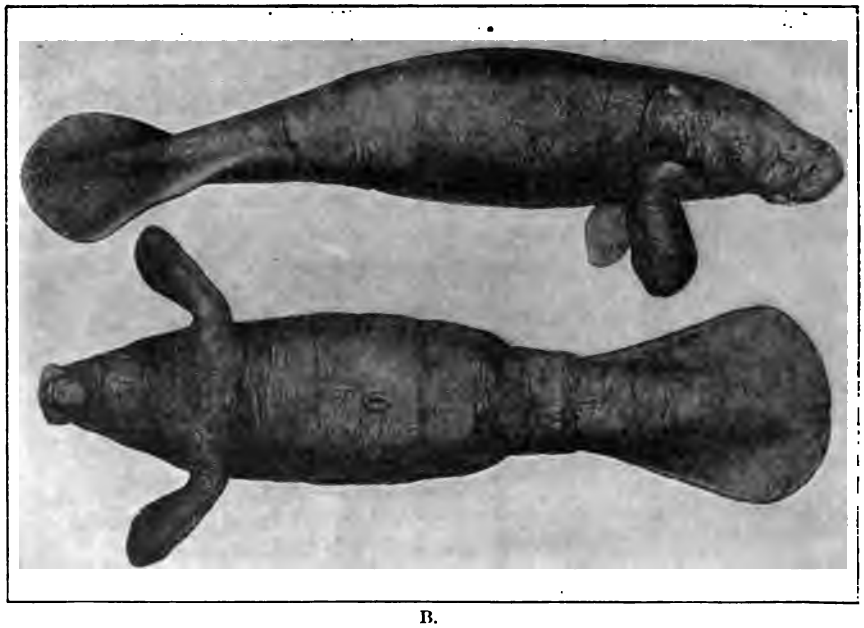
The number of teeth varies greatly. It ranges from 246 in the long-beaked dolphin to two in the bottle-nosed whale. The snout is short

[a] This idea, which is not original with Professor Abel, is, I believe, incorrect. All cetaceans, and certainly the smaller ones, progress solely by upward and downward strokes of the flukes.—F. W. T.

and rounded in some species (such as the blackfish), but in others it is shaped like the bill of a snipe.

The principal food of the cetaceans is fish. Only one species, a dolphin inhabiting the coast of Cameroon, has become herbivorous. A large number of cetaceans feed solely on cuttlefish, especially those toothed whales in which the teeth are reduced in number, such as the sperm whale and bottle-nosed whale. The Ganges dolphin (*Platanista*) lives chiefly on small fresh-water crustaceans. The whalebone whales are seldom fish eaters, although the common finback and the little piked whale are exceptions. The principal food of the whalebone whales consists of minute crustaceans and soft mollusks, which

A.



B.

FIG. 6.—The American Manatee (Manatus latirostris Harlan). A. View from the right side. B. View from below. Length about 3 meters (9¾ feet). After J. Murie.

occur in enormous masses in the open sea. The gigantic whales swallow enormous quantities of these little animals. No less than 1,200 liters (317 gallons) of crustaceans about an inch long have been found in the stomach of a sulphurbottom whale.

That the killer whale is not behind the sharks in point of voracity is evidenced by the finding of 13 (young) harbor porpoises and 15 (young) seals in the stomach of an animal 7.5 meters (24½ feet) long, all having been swallowed whole, with the exception of one seal, which was bitten in pieces.

2. THE SEA-COWS.

The sea-cows, or sirenians, are awkward, stupid creatures, which can scarcely move on land, but are excellent swimmers. In spite of their whale-like form, they must be associated with the ungulates, from which at first sight they seem very different. Their food consists exclusively of aquatic plants, and it is for this reason that they live only on the seacoast or in rivers.

The arms and hands, as in the whales, take the form of flippers. As in the whales also, locomotion is due solely to the action of the caudal fin, and the hind limbs are aborted.

A sea-cow leaves the water no more willingly than a whale. Their arms, however, are capable of supporting the body while the animals are grazing on the fields of seaweed (Tangwälder), and on this account they are still movable at the elbow, which is no longer the case in whales.

Within historical times a sea-cow, known as Steller's sea-cow, *Rhytina* (or *Hydrodamalis*), has been completely exterminated. Steller discovered this helpless animal, which was from 8 to 10 meters (26 to 32¾ feet) long, in 1741 in Bering Island. About twenty-seven years later it was annihilated.

At present only two genera of sea-cows live in the tropics. One of them, the dugong (*Halicore*), is distributed from the Red Sea along the coast of India to the Solomon Islands. The other genus, the manatee (*Manatus*, or *Trichechus*) (fig. 6), lives on the east coast of South America (ranging northward to Florida). The dugong lives exclusively in the ocean, but the manatee ascends rivers. The African manatee has been met with in the Kibali River more than 2,000 kilometers (1,243 miles) from the mouth of the Congo. The American manatee has withdrawn in part to the upper courses of the Orinoco and the Amazon.

3. THE PINNIPEDS.

The seals are at once distinguishable from the whales and sea-cows from the fact that they possess well-developed hind limbs. The tail, on the contrary, is aborted and does not end in a fin.

The manner of progression in the water is entirely different in the representatives of the three families of pinnipeds (sea-lions, walruses, and seals). The seal (fig. 7) swims by powerful back strokes of its hind limbs, which are formed like fins, and after a stroke are laid against one another and, as it were, folded together. This mode of swimming has a great advantage, because the surface exposed to the water, and hence the resistance of the water, is thereby greatly reduced. The arms of the seal serve only for steering, as in the whales.

In the sea-lions (fig. 8) the fore limbs are the sole organs of locomotion, while the hind flippers serve only for steering; exactly the opposite, therefore, of the seals. The fore feet are large and long and in form remind one of the wings of penguins and auks. They have not

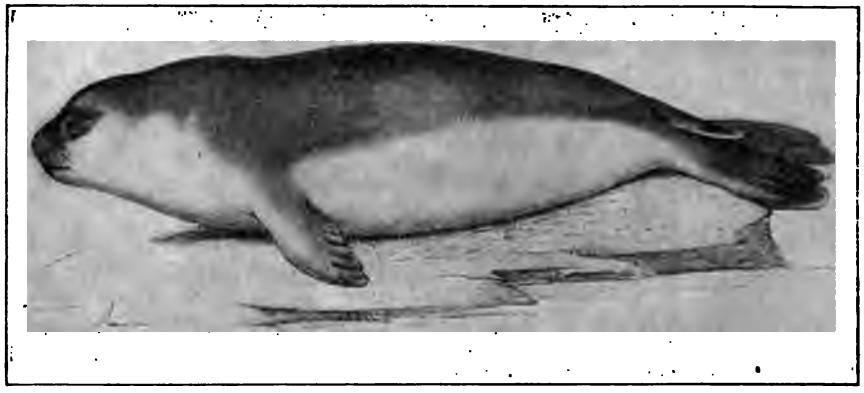


FIG. 7.—A seal in a swimming posture. (After P. Gervais.) The first and fifth toes of the hind feet are of equal length; the middle toe is the shortest. The hind flippers are contracted and therefore in the position they assume after a back stroke. The fore flippers serve only for steering.

the slightest similarity with those of whales and sea-cows. In swimming, they are turned about in a peculiar fashion like a screw.

The walrus moves in the water in such a manner that both fore and hind flippers serve in locomotion. The fore flippers move alternately, as in sea-lions and turtles. The hind flippers, on the contrary, are turned about in the same manner as in seals. The swimming motion of the walrus is, therefore, entirely different from that of the sea-lions and seals.

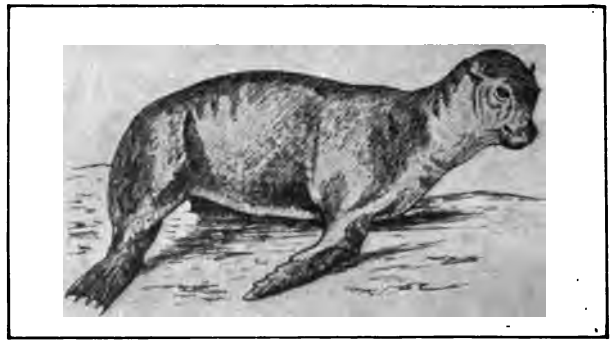


FIG. 8.—Eared seal lying on land. (After W. Haacke.) The fore limbs, which serve as propellers, are formed like the wings of penguins.

The tail is rudimentary in all three families of pinnipeds, and plays no rôle in locomotion.

The dentition of the seals is simplified. It serves for masticating food only in the walrus. In all other pinnipeds, it serves for grasping. Speaking generally, the molar teeth of the seal are serrate, with sharp cutting cusps, while those of the eared seal are single-pointed

and conical. The teeth of the walrus, on the contrary, are blunt and small, and some of them fall out early.

Among the seals belong the harp seal, the monk seal (*Monachus*), the hood seal, and the elephant seal, the last of which is the giant among seals and reaches a length of 9 meters (29½ feet). The eared seals include the sea-lions and fur seals. The northern fur seal is the best known representative.

The walrus is the only living genus of the family to which it belongs.

4. THE OTTERS.

Only one genus of otters, *Enhydris* (or *Latax*), that to which the sea-otter belongs, can be included among marine mammals, as all other otters are fresh-water animals and only occasionally go to sea. The sea-otter has a special interest for us, because its adaptation for a life in the sea has not progressed so far that the characters peculiar to otters have been effaced. If we compare the sea-otter with its allies, however, we see that its hind limbs have already become real fins, as in the seals, while the fore feet differ but little from those of land otters. It follows as a consequence of the larger size of the hind flippers that they play a more important rôle in the locomotion of this animal in the water than do the fore legs.

We have passed step by step from the whales, which are modified in a remarkable manner for life in the sea, to the otters, which show but few differences from carnivorous land mammals. The thought might arise, therefore, that the sea-otters have descended from the otters, the seals from the sea-otters, and the whales from the seals; or, in other words, that in these several types we see before us the various stages through which the development of the whales has passed. This is not the case. We have only to observe the different modes of locomotion in the water displayed by the whales on the one hand and the seals on the other, and to consider that in the seals the tail is aborted, and does not bear a fin, while in the whales the tail fin is extraordinarily powerful, to be relieved of all doubt that there are here two fundamentally different forms of adaptation for life in the sea.

Because these modifications of the seals and whales are entirely different, the latter can not possibly be derived from the former. The whales must possess ancestors in which the tail was long and well developed, so that at an early stage it could assume the labor of locomotion in the water.

Similarly, detailed comparisons show that no close relationship exists between the seals and otters, and that the seals must have taken their origin from another branch of the carnivore stem. From the otters, seals, and whales, which without exception were originally

carnivorous, the group of herbivorous sea-cows is sharply separated. Their ancestors were not carnivorous but herbivorous mammals, and they have remained true to this regimen.

II. The Mesozoic Marine Reptiles.

Since the ancestors of the whales, of the sea-cows, and of the seals can not be looked for among the living mammals, the question may be raised whether the Mesozoic marine reptiles may not be regarded as their ancestors. Indeed, on superficial observation, the well-known ichthyosaurs (fig. 9) presents the form with which we are familiar in the dolphin. The body is fish-like, the skull, as in the dolphin, extends into a long snout with numerous teeth, the limbs have the form of flippers, there is a dorsal fin which reminds one forcibly of that of a dolphin, the skin is naked, and the young are born alive.

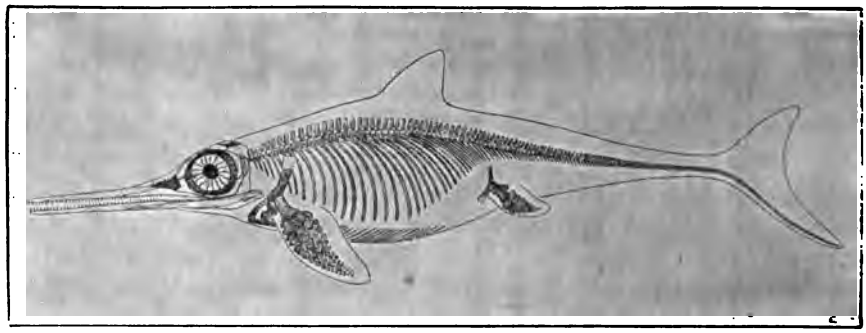


Fig. 9.—Restoration of Ichthyosaurus quadriscissus Quenstedt from the Upper Lias of Württemberg. Length about 2 meters (6½ feet). After O. Jaekel.

Opposed to these similarities of form, however, are many much more important structural differences. The ichthyosaurs were reptiles which were not related to the mammals in the remotest degree, and became extinct without leaving descendants.

On more careful observation, we see, moreover, that the caudal fin in the ichthyosaur is not horizontal, as in the whales, but vertical, as in the fishes. In addition, not only the fore limbs but the hind limbs are transformed into fins. Only the *form* of these fins can be compared with those of whales; their *structure* is entirely different.

The similarities between ichthyosaurs and dolphins can not, therefore, be looked upon as evidence of relationship. They result from a similarity of adaptation for the same mode of life. If we search among the other marine reptiles which took the place of whales in Mesozoic times, we do not meet with any form which exhibits any similarity to living mammals. In contrast with the dolphin-like ichthyosaur, stands the rotund plesiosaur, with its turtle-like body, four long fins, and a small skull resting on a very long neck. With

this is connected the peculiar marine turtles, which were modified for living entirely in the sea, and possessed a long salamander-like body and fins, and a vertical caudal fin like the ichthyosaur. They ally themselves to the snake-like mosasaurs (fig. 10), which again exhibit other forms of body.

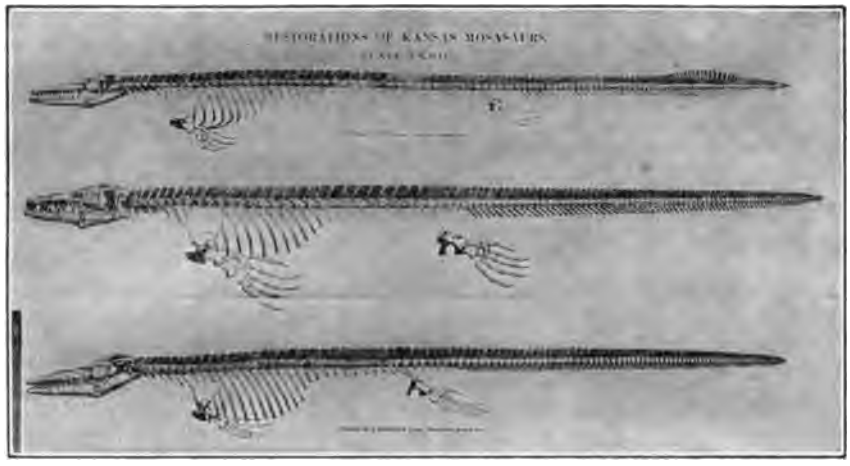


FIG. 10.—Restored skeletons of Mosasaurus from the Upper Chalk of Kansas. A. Clidastes velox Marsh. Length about 4 meters (12 feet). B. Platecarpus coryphæus Cope. Length about 4.6 meters (14 feet). C. Tylosaurus proriger Cope. Length about 7.5 meters (23 feet). After S. W. Williston.

Of all the marine reptiles, none can be the ancestor of the marine mammals. Without exception, all these marauders of the sea were representatives of separate branches of the reptile stock, which have entirely died out.

The time of the extinction of the great marine reptiles does not coincide with that of the appearance of the marine mammals. One may not at all picture to himself that the extirpation of the marine reptiles which ruled the sea at the end of the Mesozoic was due to their being supplanted and annihilated by the rising and flourishing mammals. A long time elapsed between the destruction of the marine reptiles and the appearance of the first marine mammals.

III. The Ancestors of the Marine Mammals.

The Mesozoic is the time of the uncontested dominion of the reptiles on land, in the air, and in the sea. The mammals of this epoch are known only from very rare and insufficient remains. The dominion of the mammals begins with that division of geological time which we call the early dawn of the world, ἔως καινή, or the Eocene. They first conquer the land and then take possession of the sea.

The Cænozoic falls into the following subdivisions:

II. Quaternary	2. *Present.* 1. *Glacial epoch.*
I. Tertiary	4. *Pliocene.*—Example: The upper light sea sands of Antwerp (whalebone whales, walruses, seals). The marine formations of the upper Italian lowland (whalebone whales, toothed whales, sea-cows). 3. *Miocene.*—Example: The lower black sea sands of Antwerp (whalebone whales, toothed whales, and seals). Marine deposits of the outer border of the Alps (sea-cows and whales). Clays of Nussdorf and Heiligenstadt, Vienna (whales and seals). 2. *Oligocene.*—Example: The sea sands of the vicinity of Mayence (sea-cows). 1. *Eocene.*—Example: The marine chalk of the Mokattamberg near Cairo, and of the Fayum (primitive cetaceans and the first sea-cows).

The different divisions, as for example the Eocene, Oligocene, etc., are again subdivided into Lower Eocene, Middle Eocene, Upper Eocene, etc.

FIG. 11A.

FIG. 12. FIG. 11B.

FIGS. 11 and 12.—Skulls of two primitive cetaceans from the lower Middle Eocene of Egypt. Fig. 11. Protocetus atavus E. Fraas. Length of skull 60 cm. (23.6 in.); 11a, obliquely from above; 11b, from below. Fig. 12. Eocetus schweinfurthi E. Fraas. Length of skull 90 cm. (35.4 in.). Right side. After E. Fraas.

While only land mammals have thus far been found in the Lower Eocene, the first marine mammals appear in the lower Middle Eocene—primitive cetaceans and the oldest sea-cows. These discoveries were made during the last five years in a region from which pre-

viously only scattering remains of mammals were obtained, namely, in the vicinity of Cairo and in the Fayum.

The oldest whale which we know to-day, *Protocetus* (fig. 11), differs so extraordinarily from living whales that at first sight one could hardly assign it to this group of animals. The skull, and particularly the teeth, show, on the other hand, an astonishing resemblance to the oldest land mammals.

As in the latter, the oldest primitive cetacean has 3 incisors, 1 canine, 4 premolars, and 3 molars on each side of the upper and lower jaws. As in the carnivores, the canine projects strongly. The teeth

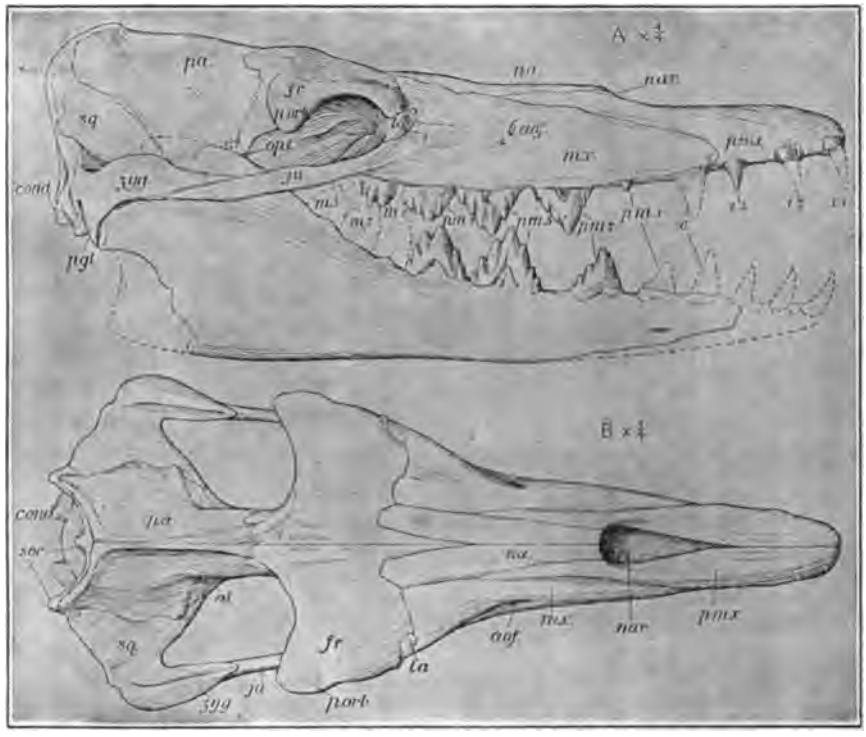


FIG. 13.—Skull of a primitive cetacean, Prozeuglodon atrox Andrews, from the lower Middle Eocene of the Fayum (Egypt). Length of skull 60 cm. (23.6 in.). A. From the right side. B. From above. After C. W. Andrews.

which follow it are two-rooted, the posterior three-rooted. The edges of the teeth are smooth. The number of teeth in this primitive cetacean must have been 44, a great contrast to the recent long-beaked dolphin, which has 246 teeth.

To this primitive form is joined another, *Eocetus* (fig. 12), which differs through the fine serration of the edges of the teeth. Then follows, also in the same deposits of the Middle Eocene s a third form, *Prozeuglodon*. (Fig. 13.) In this cetacean the th formed as in land mammals, but the edges are strongly ser

This last genus is a transition form to the later primitive cetaceans of the upper Middle Eocene. In this form, *Zeuglodon* (fig. 14), the marked difference between the incisors, canines, and anterior premolars has disappeared; the posterior teeth have lost their three roots and have therefore become two-rooted. The last molars of the upper jaw have begun to retrograde, and in one species (fig. 14) are already lost.

From the scanty remains of the limbs of this primitive cetacean which have been discovered, only one conclusion can be drawn, namely, that the arm was modified so as to form a flipper. As the tail vertebræ of the later primitive forms are very large and powerful and resemble those of the existing whales, it is certain that these creatures swam after the manner of the whales and not of the seals.

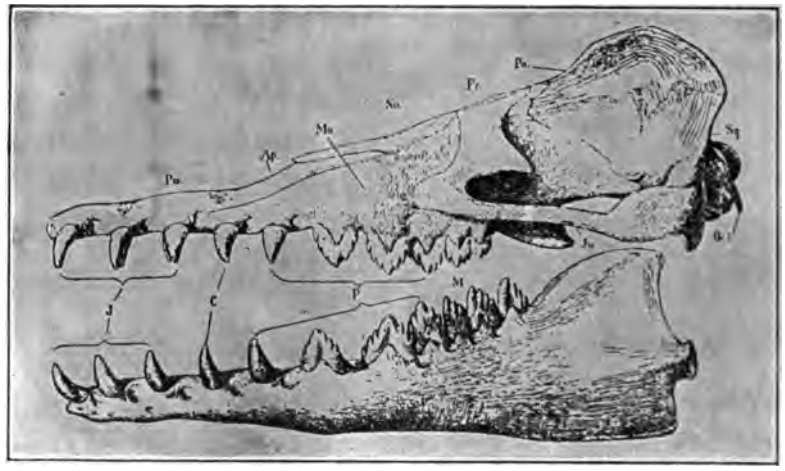


FIG. 14.—Skull of a primitive cetacean, Zeuglodon osiris Dames, from the upper Middle Eocene of Egypt. Length of skull 70 cm. (27.5 in.). J=incisors; C=canine; P=premolars; M=molars. After E. v. Stromer.

The primitive cetaceans appear to have become extinct with the latest form of the Upper Eocene. At all events, no remains from later deposits give us any evidence of a continuation or transformation of this stock. We are therefore confronted anew with a great question: Where shall we look for the ancestors of existing whales?

A small primitive cetacean from the Eocene deposits of the Caucasus, *Microzeuglodon*, gives us a clew. This appears to be the progenitor of a series which is represented in the Oligocene only by a small whale from the vicinity of Bünde in Hanover, but which in the Miocene (the next later division of geological time) reached a high development. This Miocene whale has a very full dentition. The teeth remind one remotely of those of the sharks. It is, on this account, called the "shark-tooth whale," *Squalodon*. (Fig. 15.)

These squalodons approach the primitive cetaceans of the Eocene in the form of the posterior teeth, and as in the latter these teeth in some species are three-rooted. An important difference exists, however, in the number of the teeth. While the primitive cetaceans have only 11 teeth on each side of the upper and lower jaws, in the squalodons the number is 14 or 16. The simplification of the teeth proceeds so far that the incisors, canines, and many of the anterior premolars are of the same form.

The skull of the squalodons reminds one strongly of that of existing toothed whales. The nostrils are pushed far back in the skull, an adaptation for breathing in the water. With the squalodons begins an almost unbroken series which leads to the existing sperm whale.

FIG. 15.—Skulls of two squalodont cetaceans, Squalodon. A Squalodon zittell Paquier, from the Miocene of Bleichenbach in Lower Bavaria. ¼ natural size. After K. A. von Zittel. B. Squalodon bariensis Jourdan, from the Miocene of Bari in southern France. $\frac{1}{10}$ natural size. After Lortet.

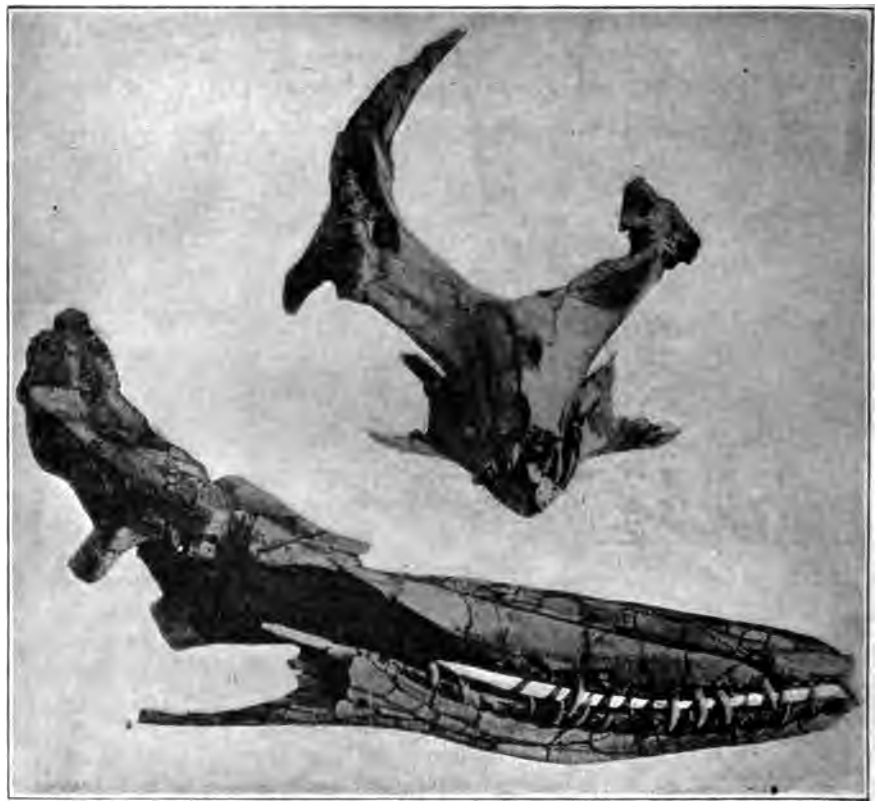
Between 1861 and 1863, when the fortifications of Antwerp were built, thousands of whale skeletons were dug up, and among them forms which show in the clearest manner how the transition between the squalodons and the sperm whale has taken place.

First we see that in the different forms of *Scaldicetus* (fig. 16) the two-rooted teeth have become single-rooted through the fusing together of the roots. The crowns of the teeth, which were originally compressed, have become conical. The cusps on the edges of the teeth have disappeared and resolved themselves into fine serrations, whose remains finally are only indistinctly seen on the crowns of the teeth. The crowns are shorter and the roots longer and thicker. The teeth stand obliquely and form a formidable grasping apparatus.

In the scaldiceti the premaxillæ, maxillæ, and mandible still bear teeth. The same is true of a whale belonging to a later formation, *Physeterula* (fig. 17), in which, however, the enamel layer of the crown is already lost.

Then follows a forerunner of the sperm whale, *Prophyseter* (fig. 18), in which the incisors fall out in early youth, while the maxillary teeth follow a little later. The upper dentition is, therefore, gradually aborted.

A.



B.

FIG. 16.—Skull of Scaldicetus patagonicus Lydekker from the Miocene of Chubut, Patagonia. A, from in front; B, from the right side. $\frac{1}{8}$ natural size. After R. Lydekker.

Then follows the genus *Placoziphius*, in which the premaxillæ and maxillæ have become entirely toothless, while only the lower jaw bears teeth, and thus we reach the stage where the existing sperm whale (fig. 20) joins on.

There are few genealogical series of animals which give us the history of a stock so clearly. Of special interest, however, is the sudden, almost "explosive," development from the squalodons to the sperm whale. The entire development is completed in a very small

section of geological time, the Upper Miocene, and since that time the sperm whales have not materially changed.

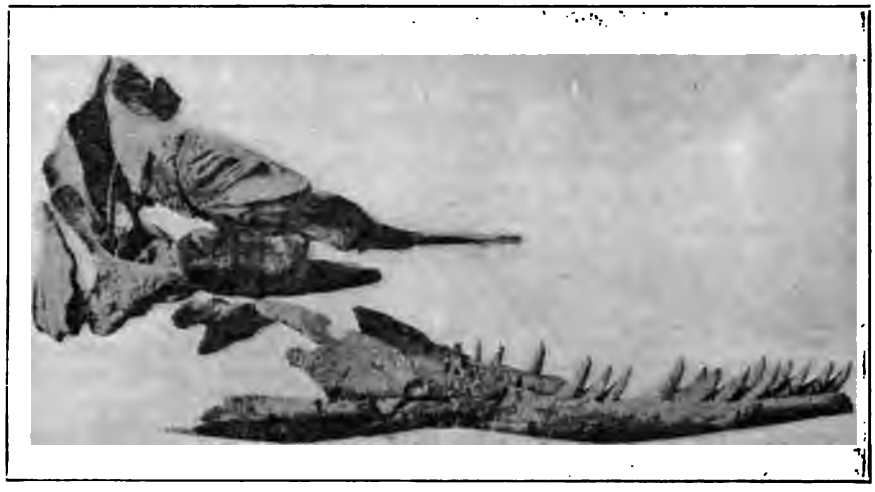
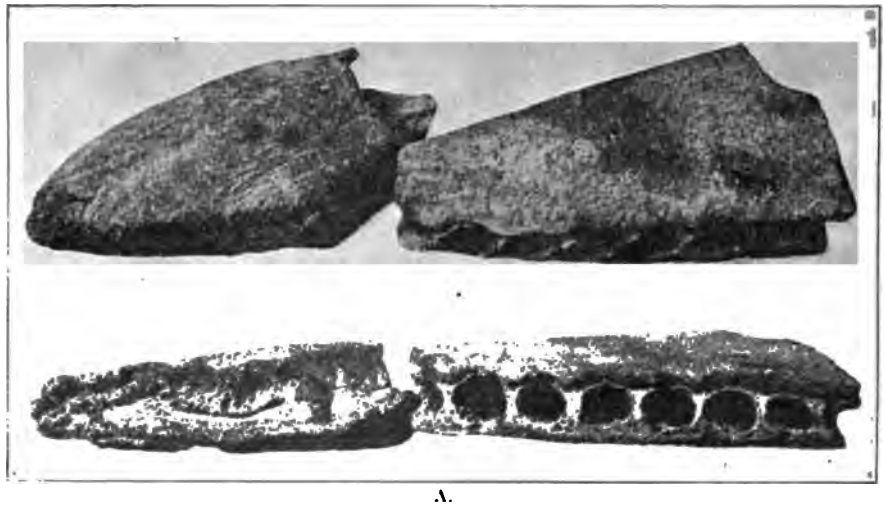


FIG. 17.—Skull of the physeterine species Physeterula dubusii Van Ben, from the Upper Miocene of Antwerp. The beak is lacking. $\frac{1}{7}$ natural size.

A second series springs from the squalodons and leads to the existing beaked whales. Here the simplification of the dentition is completed in a different way than in the case of the sperm whales.

B.



A.

FIG. 18. Anterior end of the beak of an ancestor of the Sperm whale, Prophyseter dollol Abel, from the Upper Miocene of Antwerp. 18a, from below; 18b, from without. On the left the premaxilla, on the right the maxilla. $\frac{1}{4}$ natural size.

The most important difference is that all the teeth disappear, with the exception of one or two pairs in the lower jaw. In the liv

beaked whales one finds rudimentary denticles which remain in the gums and are not cut.

In this series also we know the most important transitional forms. Fig. 19 shows the under jaw of a beaked whale from the Miocene of France, *Cetorhynchus*, in which the alveolar groove is greatly reduced

FIG. 19.—Fragment of the mandible of a Beaked whale, Cetorhynchus christoli Gervais, from the Miocene of Poussan, southern France. ⅓ natural size.

and the septa between the alveoli have disappeared. The series is developed in the same line as the sperm whales, and the transformation is similarly nearly completed in the Upper Miocene. At this time a genus of beaked whales, *Mesoplodon*, appears, which is met with abundantly in fossil form, but very seldom at the present day.

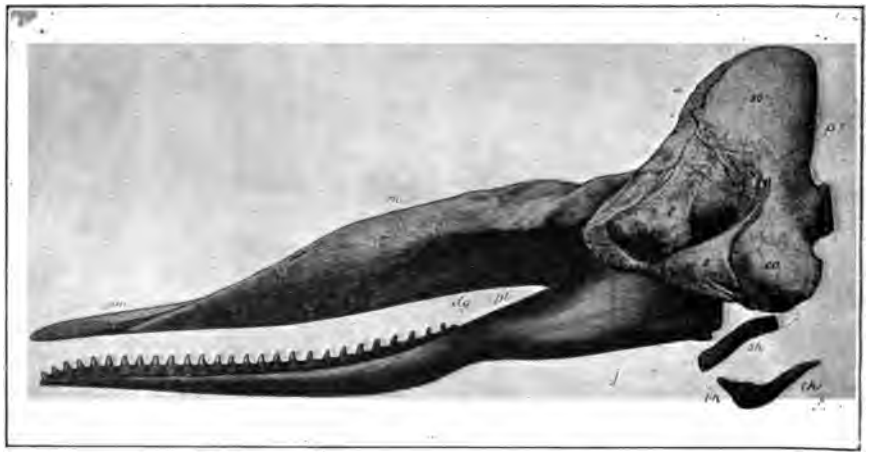


FIG. 20.—Skull of a Sperm whale, Physeter macrocephalus L. Length of the body reaches 18 meters (59 feet). After W. H. Flower. The mandible has 27 large single-rooted teeth on each side; the upper jaw and the premaxillæ which form the end of the snout are toothless.

Still another independent series springs from the squalodons, which has its highest development in the Miocene, but at the present time is on the decline. To this group belong the small South American river dolphins (*Stenodelphis* and *Inia*) and the white whale and narwhal.

While all the series thus far spoken of are still represented to-day, a fourth series, which also took its origin in the squalodons, is entirely extinct. This series comprises the long-beaked dolphins of the Upper Miocene of Antwerp (*Eurhinodelphidæ*). In one species the snout reaches nine-elevenths of the total length of the skull, an enormous proportion, which stands alone among all the long-beaked aquatic animals which have lived hitherto. (Fig. 21.)

The dolphins of the present are not the descendants of the squalodons. What their ancestors were we can not say to-day. It is sure, however, that they sprang from armored progenitors. In the Upper Miocene of Radoboj in Croatia a small-toothed whale closely allied to the harbor porpoise (*Phocæna*) has been found whose whole flipper was covered with armor, while the existing harbor porpoise retains only scanty remains of this old armor. (Fig. 5.)

FIG. 21.—Skull of a long-beaked dolphin. Eurhinodelphis longirostris Du Bus, from the Upper Miocene of Antwerp. Length of skull 106 cm. (41.7 in.).

The initial link for connecting the whalebone whales with the land carnivores is also wanting at present. Most probably they originated from the primitive cetaceans. But certainly they passed through the stages of toothed whales, as numerous denticles are present in the jaws of whalebone whale embryos. The oldest whales of this kind appear in the Miocene. They are very small, but approach very near the finbacks.

While, therefore, the origin of some groups of whales is enveloped in obscurity, important and very rich discoveries in the Eocene of Egypt have shown us from what ancestors the sea-cows originated and how their stages of development proceed.

Contemporaneously with the oldest primitive cetacean appears the oldest sea-cow, which has received the poetic name of the "animal of the dawn," *Eotherium*. With this appears a second, more highly developed genus, *Protosiren*. (Fig. 22.) The most salient character by which the oldest sea-cows are distinguished from the existing ones is the possession of all four limbs. The dentition is as complete as in the oldest primitive cetaceans. A series of characters points with certainty to a near relationship with the pachyderms. Elephants and sea-cows doubtless had the same ancestors.

The hind limbs, which are still functional in the oldest sea-cows from the lower Middle Eocene (fig. 23, I), in those of the upper Middle Eocene, have already become functionless (fig. 23, II). The pelvis, which originally consisted of ischium, ileum, and pubis, has degenerated. The obturator foramen has disappeared. (Fig. 23, II.) The acetabulum has become smaller and rudimentary. (Fig. 23, III.)

By making use of later forms we can trace step by step the course through which the degeneration of the pelvis and of the femur has

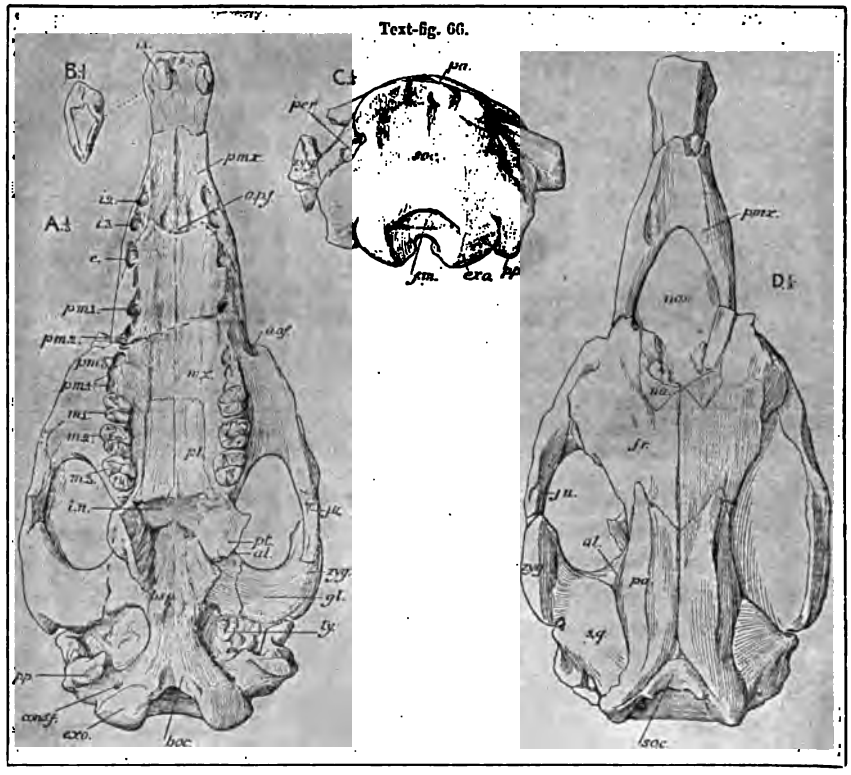


FIG. 22.—Skull of a sea-cow, Protosiren fraasi Abel, from the lower Middle Eocene of Egypt. Length of skull 36.5 cm. (14.4 in.). A. Skull from below. D. From above. C. From behind. B. Right tusk, or anterior incisor. ⅔ natural size. After C. W. Andrews.

progressed. The pubis gradually became smaller (fig. 23, II, III, IV) and disappeared entirely in a sea-cow from the Miocene of Austria. Finally, only a long rod of bone remains, the upper part of which consists of the ileum and the lower part of the ischium, as in the extinct Arctic sea-cow and the existing dugong.

The South American manatee has retained a rudiment of the femur, but this is only about 18.5 mm. long and about 2.5 mm. thick, while the animal itself reaches a length of 3 meters (10 feet). (Fig. 24.)

In no other group of mammals, perhaps, can the stages in transformation be followed so clearly as in the sea-cows. This is due to the fact that these animals inhabited the seacoast, and that conse-

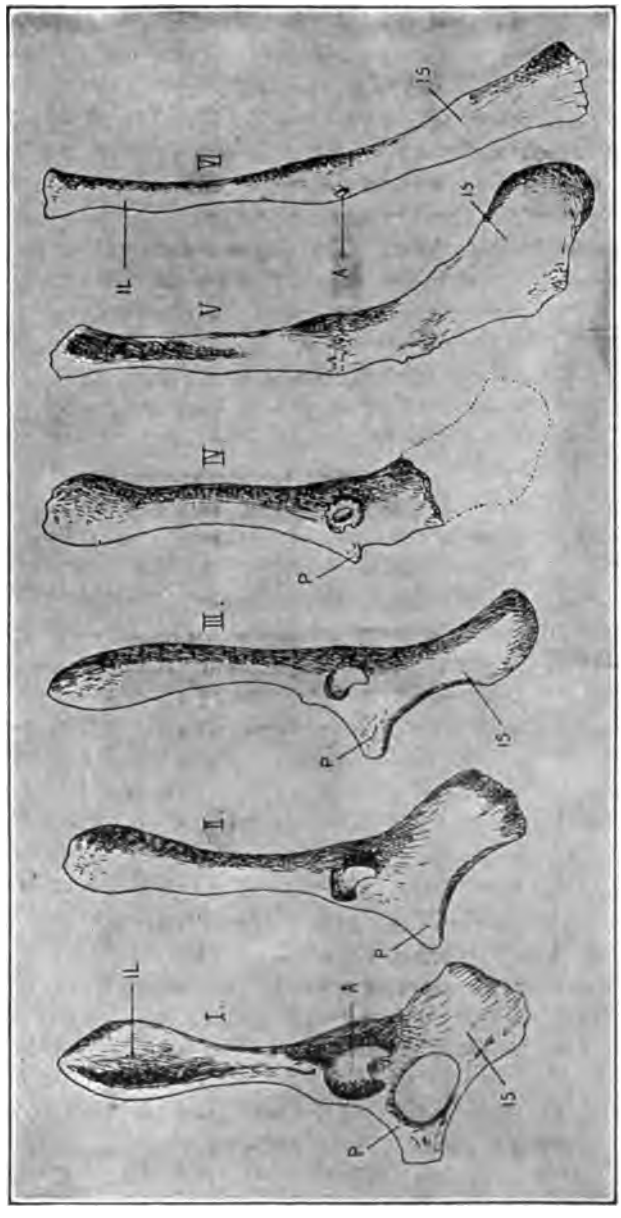


FIG. 23.—The gradual reduction of the left pelvic bone of the sea-cow IL, ileum P pubis S ischium A, acetabulum for the femur. The series of figures is chronological from left to right. Fig. represents the pelvis of the oldest sea-cow and Figs. 5 and 6 the pelvis of the Dugong. One may observe how the pubis gradually becomes aborted and finally disappears. The ischium becomes more slender and finally unites with the ileum to form a bent rod of bone. The acetabulum becomes rudimentary and in the pelvic bone of the Dugong (Fig. 6) appears only as a small oval surface. I. Eotherium lower Middle Eocene). II. Eosiren (upper Middle Eocene). III. Halitherium (Oligocene). IV. Metaxytherium (Miocene). V. Dugong of Australia. VI. Dugong of the Red Sea.

quently their remains have been met with abundantly in the marine Tertiary deposits of Europe. The whales live largely in the high seas and a carcass is only occasionally driven on shore by currents.

A graveyard of whales, such as exists in the Upper Miocene and Pliocene bay of Antwerp, is a quite unique phenomenon.

The sea-cows arose in the Mediterranean region in the Middle Eocene. Until the Pliocene they were abundant on the seacoasts of Europe. From thence the ancestors of the dugong took their way toward the east and those of the manatee toward the west. Thus it at once becomes clear why the range of the two living genera of sea-cows is so sharply separated, and why such fundamental differences exist between the dugong and the manatee. They separated at a very early time in the Mediterranean from the main stock of the sea-cows, which is now extinct, while the branches continue.

Let us return again to the whales. The degeneration of the pelvis in the sea-cows which we can follow directly, gives us the means for solving the problem of the rudimentary hind limbs of the whales. If we compare the pelvis of the bowhead or Arctic right whale (fig. 25) and that of the finback (fig. 26) with the pelvis of the oldest sea-cows, the correspondence becomes at once apparent. In both cases the ileum, pubis, and ischium are in all respects similarly formed. The obturator foramen has disappeared, the acetabulum for the femur is no longer functional. The ileum is very long, the ischium and pubis aborted. Most significant, however, is the position of the remains of the pelvis in the body of the whalebone whales. The pelvis of the Arctic right whale is turned 180°, as compared with that of the finback. The rudiment of the pelvis of the toothed whales corresponds also entirely with the forms found in the dugong. It follows that the reduction of the pelvis and of the hind limbs in both not closely allied groups, the whales and the sea-cows, must have proceeded in exactly the same order.

FIG. 24.—Left pelvic bone of the American Manatee, Manatus latirostris Harlan. ½ natural size. IS., ischium; F., remnant of the femur. The ileum and the pubis are lacking.

The example shows in the clearest manner the importance of the study of fossil forms, as it is only through a more exact knowledge of them that we can properly *understand the structure of living animals.*

If we turn to the primitive history of the seals, we are forced to say that their origin is not yet clear. The most probable supposition is that they originated from bears. Paleontology unfortunately leaves us in the lurch, as the oldest seals of the Miocene already show all the characters of existing seals. But through the multifarious observations which at present extend throughout all civilized countries, it

will doubtless be possible to bring this problem to solution some time soon.

If we review the results of our investigations, we see that the

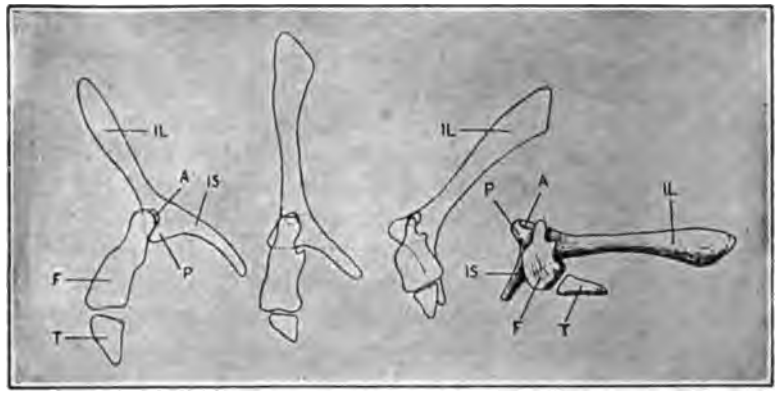


FIG. 25.—Left pelvic bone of the Bowhead or Arctic right whale, Balaena mysticetus L., seen obliquely from without. About $\frac{1}{4}$ natural size. From left to right, the first three figures make it intelligible how the present position of the pelvic bone of the Bowhead was assumed. The upper end of the ileum has rotated backward, until the hip-bone lies horizontally. The anterior end is toward the left, the posterior toward the right. IL., ileum; P., pubis; IS., ischium; A., acetabulum; F., femur; T., tibia (cartilaginous).

marine mammals do not form a single group, but belong to series of entirely different forms, not closely related.

The whales originated from very old land carnivores, the sea-cows

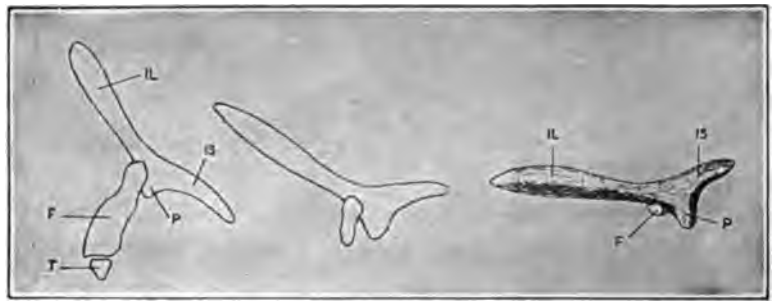


FIG. 26.—Left pelvic-bone of the Common Finback, Balenoptera physalus L., seen obliquely from without. About $\frac{1}{4}$ natural size. The left and middle figures show how the position of the hip-bone of finback assumed its present position. The upper end of the ileum has turned downward forwards, so that the bone is horizontal. The anterior end is toward the left, the posterior toward the right. Abbreviations as in Fig. 25.

from elephant-like pachyderms, the sea-otter from ordinary otters, and the seals probably from bears.

We have seen that, in spite of many similarities in the form of the body, the whales are not allied to the ichthyosaurs; also among marine mammals there is a series of corresponding lines. Thus we

find in the whales and sea-cows—two widely separated stocks—a horizontal caudal fin, rudimentary hind limbs, fin-shaped fore limbs, a more or less naked skin, etc. Let us, however, look more closely at one of these structures which appear so similar. The flipper of a marine mammal is always much broader than the fore limb of a land mammal. The fin must be broad if it is to serve as a good steering apparatus. In the whales the broadening of the fin is accomplished by the broadening of both lower arm bones, so that the bones themselves are increased in breadth antero-posteriorly. The space between the radius and ulna is small. (Fig. 27, I.) In the sea-cows, on the contrary, the broadening of the fin results from the increased space between the radius and ulna. The radius is bent forward strongly, while the bones maintain nearly their original size. (Fig. 27, II.) In the seals, finally, the same result is reached

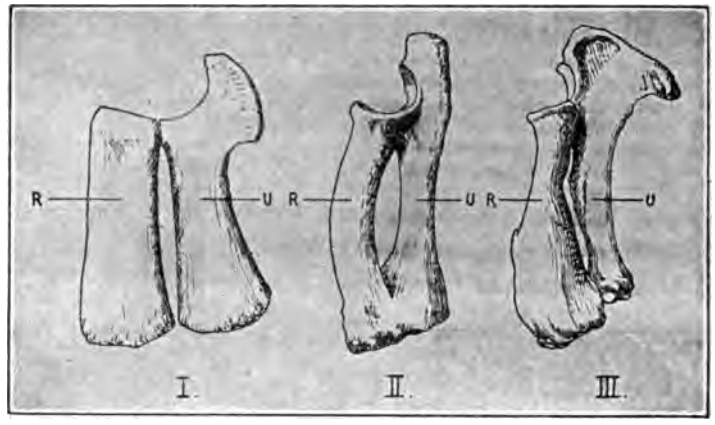


FIG. 27.—The left lower arm-bones of a toothed whale (Fig. I), a manatee (Fig. II), and a seal (Fig. III), seen from without. R., radius; U., ulna.

by the radius being increased in width at its lower end and the ulna at its upper end, while the spaces between the bones remain very small. (Fig. 27, III.)

Thus the same result, the formation of a broad fin, comes about in three different ways. We can state that in briefer form somewhat as follows: *Like form, with different structure.*

To follow the relations between the form of the body and the structure of the body in all particulars is essential if one wishes to approach the problem of the affinities of animals one to another. The history of the separate stems of the marine mammals must be constructed on foundations entirely different than those upon which the similarity of the form of the body is based. We recognize here again, as everywhere, the dominating influence of mode of life on the structure of organisms, which in different groups produces the phenomena *of con*vergent adaptation.

THE MEDITERRANEAN PEOPLES.[a]

By THEOBALD FISCHER.
University of Marburg.

The Mediterranean region for many years has stood in the foreground of international politics. Morocco has drawn the attention of the whole world to her by the events happening on her coasts; events which have already resulted in the occupation by the French of the eastern frontier town Ujda, near which Bu Amara still holds sway; events which have been echoed in and around Casablanca, in all of Morocco, in the other Atlas countries, and in fact all through the world of Islam.

In comparison with the active commercial interest which apparently all the nations of Europe take in the Mediterranean, the inhabitants of these countries have been almost entirely in the background. That they are so little known and have been deemed hardly worthy of consideration has again and again caused events very surprising to the European diplomats and people in general. The purpose of this paper is therefore to give a general outline of the variegated mixture of races on the shores of the Mediterranean and in the adjoining inland countries, with an account of their numbers and distribution. The figures are given in round numbers, sufficiently accurate, however, for the present purpose. As a matter of fact, it would be difficult for anyone to tell exactly how many Berbers and Albanians there are, or even the number of Greeks and Turks.

The most important results of this investigation, I should say at the very beginning, may be considered with these three statements before us:

1. The Mediterranean countries are as a rule very thinly populated, and the tendency is for the inhabitants to remain chiefly along the coast.

2. One-third of all the inhabitants of the coast countries of the Mediterranean are of one race—the Italian.

[a] Translated, by permission, from the Internationale Wochenschrift. Berlin, September 7, 14, 21, 28, 1907.

3. The Berbers of the Atlas Mountain region deserve much more consideration than heretofore has been given them.

The old function of the Mediterranean, that of being the source of culture for the whole world, faded further and further into the background in the middle ages. The Romans had united the whole territory under one government and in this way had caused a great uniformity in manner of life. In the Roman period all ethnic differences were more or less completely veneered by Roman culture which graded into Hellenic in the east. The so-called migrations have changed this comparative uniformity, attained in a long historical period, into the variety of races seen at the present day. The entire race map of the Mediterranean has been altered.

In many cases this complexity is only apparent, for frequently we find the primitive races hidden under a new language and a new religion which they have adopted. We may well recall as an example that the very mixed population of Asia Minor, including the Celtic Galatians, at one time gradually acquired the Greek language and the Christian religion, while to-day the same people more often speak Turkish and are Mohammedans. Only four Mediterranean peoples have preserved both their speech and racial peculiarities from the period before the migrations, and this has been possible only on account of the mountainous, inaccessible, and unattractive nature of their countries. These are the Basques, the Albanians, the Berbers, and the Greeks.

The first two have diminished in numbers to a small remnant and seem doomed to extinction as races at no very distant day. In spite of this, however, both have played a prominent part in recent history. The Basques were the supporters of the Carlist uprising in Spain, and the Albanians have been a great factor in oriental questions. The Basques are the descendants of the ancient Iberians. They have kept to the valleys of the western Pyrenees and to the neighboring Basque Mountains, named from them, living partly on French and partly on Spanish soil between Bilbao and Bayonne, but, through emigration, especially in the nineteenth century, to the La Plata States, and through absorption, they have been reduced to about a half a million in number. The Albanians sprang from the ancient Illyrians, who have been able to hold their position only in a portion of their original territory—the most inaccessible middle stretches of that great folded girdle of the earth's crust found on the west side of the Balkan peninsula and which may appropriately be called "a land of perseverance." Their long struggles, first with the Slavic overflow and then with the Turks, under whose oppression great numbers emigrated to Greece and Italy during the fifteenth century, did not exterminate them. In southern Italy as far as Sicily these Albanians number now about 80,000, although they ap-

pear to be almost entirely absorbed by the Italian culture, or in the process of assimilation. Still more Albanians have probably been assimilated by the Greeks. The Albanian cattle raisers and farmers quickly developed into mariners, with the result that many of the naval heroes of the Grecian struggle for independence were of Albanian descent. In southern Albania and Epirus, also, so far as they adopted the Grecian religion, they willingly adopted Grecian customs. What is fatal for them, however, more than their actual position in civilization, is their separation, because of racial peculiarity and the nature of their country, into many little clans, often in deadly feud with one another, and also their religious tripartition. From the south they are drawn into the Greek Church; from Italy into the Roman Catholic, and in Turkey they have been partly won over to Mohammedanism. There are many of them spread all over Turkey as soldiers and officials, often in high positions. But notwithstanding their pronounced warlike characteristics, by reason of which they form the Sultan's bodyguard, and lend material aid to the Turkish armies in their conquests, and their large number of a million and a half, they are a factor of less consequence than might be expected, because of their scattered condition.

Although scarcely subordinate, they nevertheless appear to be the principal support of the Turkish ascendency on the west side of the Balkan peninsula. Italy, in competition, is striving to win over the Roman Catholic Albanians, who educate their priests principally in Rome and thereby is endeavoring to secure a firm foothold in the peninsula, even in opposition to the Hapsburg monarchy.

Scattered over the southeastern European peninsula there are still remnants of the pre-Roman primitive peoples in the guise of the Rumanian speaking Aromunes, Zinzares, or Walachians. In the twelfth century these still held a considerable part of Thessaly, then known as the great Walachia. They are largely lacking in national feeling, belong to the Greek church, and incline toward Grecian customs. Many speak three languages (Turkish, Rumanian, and Greek). In spite of the fact that they number hardly 200,000, they have recently been prominent politically for the reason that Rumanian envoys have been striving to draw them, especially the Macedonian Walachs, away from the Grecian influence.

In Asia Minor also there are still significant remnants of aboriginal peoples, who on account of their religion consider themselves Greeks and are Hellenizing themselves by founding Greek schools and employing Greek teachers. Likewise many—in fact, according to the opinion of those who best know the conditions, the majority—of the so-called Turks of Asia Minor, and the related Mohammedan sects who form the remnants of the original people, are doing the same thing, which renders it difficult to secure accurate information c

cerning them. The Celts (Galatians) who in the third century B. C. wandered into the northern half of the highlands in the interior of Asia Minor, can still, even when Mahommedan and speaking Turkish, be easily distinguished by their light brown hair and blue or gray eyes, from the native Cappadocians with their jet black hair, narrow faces, and peculiar noses.

In an entirely different category from these disappearing remnants are two other aboriginal peoples, the Berbers and the Greeks.

The Berbers, who belong to the Hamitic group, are an extraordinarily interesting race, whose language and peculiarities have been studied far too little on account of the fact that even to the present day they energetically resist everything foreign. The principal region where they live, the Atlas mountain territory, or Little Africa, was formerly called Barbary after these people, but this name, for no good reason, seems to have passed into disuse in modern times.

In place of the name Berber, there is generally used a term, spread by the French in Algeria, namely, the word Kabyle. This word means nothing more than tribe. The comparatively pure Berbers of the high coast range in Algeria, eastward of Algiers, are called Kabyles, and likewise the mountainous region of Jebel Jurjura is called Greater Kabylia, and the mountainous region east of Bougie is known as Lesser Kabylia.

The attention of the entire world has recently been centered on the Berbers. Once before in the middle ages these people played a very important part in the political and social development of the world. The Berbers were predominant in the armies that conquered Sicily and Spain and they were very prominent among the "Arabic" teachers and artists of that time.

The Aghlabites of Kairwan, founded in 669 A. D. by the Arabians under Sidi Okba, were Berbers, among whom scientific life had its beginnings in the ninth century. Berbers also were the Fatimides who have dominated in Mehedyia since the beginning of the tenth century, and the Zirides who took up the government of Tunis in place of the Fatimides when these transferred their capitol to Egypt.

The sect of the Almoravides, made up of Berbers of the desert who had gone over to Mohammedanism, conquered Morocco in 1060 A. D. under the leadership of Abu Beker. His successor, Yussuf Ben Tashfin, founded Marrakesh and out of the present day Morocco and western Algeria formed a great empire, to which he also linked Spain. An even still greater territory, from Tangier to Barca, was held in the sway of the Almohades, who were another essentially Berber sect and dynasty. This brilliant epoch of the Berber domination lasted from 1145 to 1269. Partly in their service, the alien Arabic tribes spread out farther and farther and as bearers of Mohammedanism forced their language and to some extent their customs upon the Berbers.

The kingdoms and dynasties of the Merinides in Fez, the Zianites in Tlemcen, and of the Hafsides in Tunis (1228) were also essentially Berber. The fall of these kingdoms started with their incessant civil wars, and disintegration was so rapid in the fifteenth century that soon a general state of anarchy prevailed, and the overthrow of Tunis and Algeria by the Turks in the sixteenth century thus became an easy matter. Only Morocco was able to preserve its individuality, and has ever since then been an independent state.

The flourishing condition of Tunis and a large part of Algeria in Roman times must not be forgotten. The Roman soldiers and officials were there only in comparatively small numbers. Colonization in masses had not taken place and the greater part of the population had Phœnician and Berber names, even if somewhat Latinized. Whatever developments in culture from that time recognizable now are to be ascribed to the Berbers, and give good evidence of the great rôle played by the Berbers in the "Arabic" period.

These people offered the Romans a very hard fight before succumbing. The Arabs first appeared in Tunis in the year 647, but is was not until 669 that they fully subdued this country and organized it as a province under the name Ifrikia. In 685 Okba was killed by the Berber chief Koceïla, and the Arabs were completely expelled from Ifrikia. Every pilgrim from Biskra visits Okba's grave in the little near-by oasis Sidi-Okba. Koceïla established his own dynasty at Kairwan, which had been founded by Okba, and united the whole eastern Atlas region into one kingdom. Koceïla succumbed in 690 to another attack of the Arabs, but the Princess Dina of the Zenata (a tribe of the eastern Aures Mountains), commonly known as Kahena (Priestess), organized the defense and again drove out the Arabs. It is characteristic of the Berbers that a woman should play such a part. Other Berber tribes also had women as rulers.

In 703, however, deserted by the Berbers who were again embroiled in civil war, the Princess was overpowered by a fresh onslaught of the Arabs. At that time 12,000 Berber warriors were forcibly converted to Mohammedanism and incorporated in the Arabian army.

After this many of the Berbers, led on by the booty in prospect, and by the cleverness of the Arabs in making their interests identical, joined with the Arabs of their own free will. Tarik, the conquerer of the Visigoths, was a Berber.

The Berbers from early prehistoric times have inhabited the Mediterranean countries of north Africa from the Red Sea to the ocean and the Canary Isles, although they have been expelled from parts of this region and deprived of their language in favor of Arabic, under the influence of Mohammedanism, and in other ways are more or less Arabicized. They have maintained themselves in the purest condition in the mountains, especially those of sequestered and out of the

way parts of Morocco. The inhabitants of this country are not Arabs, as investigators once thought, and as superficial observers still imagine, but almost exclusively Berbers. The question as to whether the Berbers in a prehistoric age migrated from western Asia or Europe to their present territory has been much debated. The weight of evidence is first on one side and then on the other, but research seems rather to incline toward the European theory. The recent expression of opinion of Bertholon, the French physician and anthropologist, based on investigations of the prehistoric antiquities of northern Africa, is on the side of a migration from Europe. Bertholon says that the builders of the megalithic monuments (Dolmen, Menhir) of Tunis and east Algeria are of the same race that left behind similar monuments in Europe. The striking resemblance also of certain implements has indicated a relationship of the Berbers and the Basques. This is also considered probable for linguistic reasons.

The prominent French north African investigator, Charles Tissot, declares himself in favor of the migration from Europe, because the blond type of Berber is most frequent south of the Straits of Gibralter and becomes less frequent toward the east. The period of migration must be set at about 1500 B. C., since the monuments of the nineteenth dynasty in Egypt already represented the Libyans as a blond and blue-eyed people.

The Berber tribes of Juala and Uled Hannech in Algeria, the Krumir of north Tunis and the Shaamba of the Algerian Sahara even to this day erect sepulchers which resemble the megalithic tombs. The so-called "grave of the Christian woman" (tombeau de la chrétienne), really the grave of a Berber princess, west of Algiers, which is so much visited by travelers in Algeria, and the so-called Medracen, the grave of a Berber prince (Massinissa?), between Constantine and the Aures Mountains, in a country at present an absolute desert, are nothing more than finished forms of these megalithic tombs. The tent dwellers of Tunis even to-day use the same types of clay vessels as those found in the megalithic grave chambers. In other respects also the European influence in ancient times may be recognized. Certain peculiarities in the physical type of the Berbers may likewise be traced far back. With these peculiarities as a test the ancient Numidians are to be differentiated as true Berbers from the Libyans, the Afri, whose name is still borne by the continent, from the Maxyes, and from the Gätulians of the southwestern Atlas region. These tribal divisions have persisted even to the present day and often have proved to be fatal to them.

Many of the tribes named by Ptolemy are recognizable to-day in Morocco. In the Mazikes we recognize the Masig, the tribal name which the Berbers of northwest Morocco use. His Autololes are the Aït Hilala, his Macenites the Miknassa, his Bacuatae the Berguâta,

and the name Mauren (Moors), from which in earlier times Morocco was called Mauretania, is derived by Tissot and Quedenfeldt from the Semitic Maurim, which, literally translated, corresponds to the term which the Moroccans now often apply to themselves, el-garbaua, the people of the west. The name Berber was known before the appearance of Greeks or Romans in north Africa, and still clings as a special collective name, Brêber or Berâber, to the tribes in the high central Atlas region of central Morocco. Those of the southwest are distinguished from them as Schlu or Schlöh, those of the north as Amaziges or Amazirghes. As in ancient times, there is now in Nubia the city Berabra. Somaliland is called Barbaria, and another Berberland lies in the country of the Troglodytes between the Nile and the Red Sea south of the port of Berenice. These names indicate the wide distribution of the Berbers in former times. Even the cranial measurements of the old Egyptians show a similarity to those of the Berbers. It is to-day an unquestioned fact that the Guanches of the Canary Isles were Berbers. Berber inscriptions are found from Cyrenaica, at present inhabited by Arabs, all the way to the Canary Isles and far into the Sahara.

The territory at present inhabited by the Berbers reaches from the oases of the Libyan desert to the ocean, and includes the entire western Sahara as far as the mountain oasis of Aïr and the bend of the Niger at Timbucto, and even Senegal, which owes its name to the Berber tribe Zenaga, a people speaking a Berber dialect, who migrated or were driven there from the southern Atlas valleys only since the sixteenth century. All the so-called Moorish tribes whom the French have encountered in Senegal are more or less pure Berbers. Everywhere in northwest Africa the French and Berbers are standing in opposition to each other. The Tuaregs of the western Sahara, who can be considered now as conquered by the French, are Berbers who were forced into the desert only in the middle ages, and who must be considered among the least mixed of all the tribes. Their incessant struggle with starvation in a land so scanty in products has reduced them to an astonishingly small number and transformed them into desert bandits. According to the most recent French estimates the two great tribes, the Hogar and the Asjer, can place, respectively, only 1,200 and 300 warriors in the field. The language of these people is entirely free from Arabic words. They possess a script of their own, which is used, however, only for inscriptions on their shields, on rocks, and for verses at their occasional fests.

The Shaamba in the Algerian Sahara, who were not much more than bandits, but who have been entirely subdued, are also Berbers. The same is true of the inhabitants of the oasis groups, Tuat,

Gurara, and Tidikelt, recently taken by the French. They belong to the old Berber tribe, the Zenata, and number not 400,000 as is usually assumed, but only 60,000, which indicates that this region is also very sterile. Berbers make up almost entirely the inhabitants of the oases of Wed Rir and the Tunisian Sahara, and also the people of the oasis studded desert plateaus extending from the bend of the Lesser Syrtis at Gabes to the western limits of the Greater Syrtis. The semi-nomadic tribes in the hilly country extending along the coast south of the Atlas Mountains to Cape Juby are likewise Berbers.

The principal home of the Berbers, however, is the Atlas region, although until recently they were all considered Arabs, on account of the general prevalence of the Arabic language and because the French have long persisted in the unfortunate error of not differentiating between Arabs and Berbers, and have generally spoken only of Arabs. Yet how fundamentally different are they in physical and mental characteristics!

The number of pure Arabs in all northwest Africa is very small. Even the conquering invaders were few in number, both actually and in comparison with the Berber folk which they encountered. For how could any great number of truly nomadic people be produced from thinly populated Arabia? It was a small army according to our ideas. The results they accomplished were due to the idea that the soldiers represented, the reckless fanaticism which possessed them, and the disastrous political and social condition of the people they encountered.

The first Arab influx of any great extent took place in 1050 A. D., when the central Arabian nomad tribes Uled Hilal and Uled Soleïm, amounting at most to about 250,000, entered the country. With the coming of these nomad hordes the wasting of the country began. Part of them also scattered over the Saraha, and being herdsmen they appropriated the plains and valleys by preference, and forced the Berbers into the mountains. They penetrated gradually even into the extreme western parts into the plains of the Atlas foreland of Morocco, where there are to-day Arab tribes like the Amar, who live a little south of Tangier, the Khlot and Tliq, between El Ksar and Larash, the Howara in Sus and the Vled Delim south of Tensift, who have maintained themselves in such a pure state that they can be recognized as Arabs by their physical peculiarities, although they have assumed many of the Berber characteristics. They have remained nomads to this day, or at best are seminomads even under the influence of the most favorable conditions of land.

How many pure Arabs there are in the Atlas region is very difficult to state. Hamy has recently estimated them to be about 60,000 in Tunis, out of the one and a half million inhabitants. The tribes of Hamema in south Tunis near Gafsa and the Riah between Ed Djem

and Medjez el Bab are Arabs. Tunis being an open and accessible country is especially fitted to encourage a mixture of the two races and to allow the Arabicizing of the Berbers to progress most rapidly, although the Berber is ethnically predominant. It is a fact that, except in the island of Djerba and the mountains of Arad in south Tunis, the Berber language is left only in a few villages of northern Tunis in the region of Enfida (Tacruna, Djerada, Zriba). The dialect of these villages is like that of the Shauia of the Aures Mountains. The physical type of the majority of the inhabitants, however, and their customs are just the same as Sallust and Pomponius described. The Gurbi (huts made of twigs) are Sallust's "mapalia." In Algeria, where the French have neglected to establish the relation in numbers between the Arabs and Berbers, an authority has stated that their number is so small that they will entirely disappear in the near future. The same is true of Morocco. These facts are less apparent because many Berber tribes are so far Arabicized that they have not only given up their language and, in many cases, adopted Arabian customs, but consider themselves Arabs and announce this as a fact. I observed this state of affairs among the Freshish, a seminomadic tribe of central Tunis, descendants of the Frexes, who have lived in the same place for two thousand years. Their neighbors, the Majer, the Matmata, and the Urghemma, really a league of tribes, are also Berbers. The people of the Kerkenah Islands and of Jerba seem to have maintained themselves in a very pure state. Among themselves they speak only Berber. The well-known Krumir and the Mogod in the mountains along the northern boundary of Tunis are likewise Berbers. The former number 6,500, the latter 5,900.

The Rhiata, known for their wild freedom of life, who are the guardians of the most important route of commerce which runs along the geologic and orologic boundary line between the Rif Mountains and the Moroccan Atlas region from Fez toward the east, and connects the river country of Muluya with the Atlas foreland of Morocco, consider themselves Arabs, although they are pure and typical Berbers and still speak Tamazirt to some extent.

How this Arabicizing is accomplished may be very well observed around Tangier. All the environs of Tangier and all the villages in sight of the city were settled during the last two centuries by military colonies of the government, the people of which came from the Rif region and almost all of whom even yet recognize the fact that they originated there. These colonists have now formed a new tribe, the Fahçya, but since they are economically entirely dependent on Tangier, for whose protection their colonies were established, they have acquired the Arabic speech more and more. The villa s on t
southerly slope of the small mountain range to the west d
gier, on whose western end stands the light-house of (

are the only places where Berber is still spoken, and this is because of their isolated location.

Those peasants whom visitors to Tangier see in the markets and think are "Arabs" are absolutely pure Berbers. If one of them was dressed like a German peasant no one would doubt but that he was really what he seemed. The inhabitants of the city of Tangier itself are naturally also very much mixed with the Berber element. The tribes that inhabit the country back from the coast cities of Morocco, which has been so much discussed of late, are all more or less pure Berbers and in some degree are seminomads. This is also true of the Shauia around Casablanca, the Dukkala around Masagan, the Shedma around Mogador, the Semmur and Zair around Rabat, the Beni Ahsen on the lower Sebu, and farther in the mountains the Zaian, Geruan, Beni Mgild, Beni Mtir, the Beni Uarain, whom De Segonzac calls the ugliest of all the Berbers, the Aït Yussi, and others; in fact, every tribe with whom the French will next have to deal are Berbers. Some of these tribes climb high and penetrate into the mountains in the summer time with their herds and are very active and difficult to control. They are able to elude every superior force, as the Sultan's armies have so often discovered, and can inflict the severest losses on their enemies by enticing them into ambuscades.

In Algeria the French have contributed enormously to the adoption of the Arab tongue by the Berbers, because they have for decades considered all the natives as Arabs and have forced Mohammedan government, law, and customs and therefore the Arab language upon them. Yet, in 1859, Hanoteau, a profound student of the Berbers, estimated the number of the Berbers in Algeria to be 850,000, the great majority of the native population, while he reckoned the Arabs at only one-sixth this number.

The Marquis de Segonzac, another ethnological authority, says there are no longer any pure Arabs anywhere in Morocco.

The Berbers physically are an extraordinarily powerful and sturdy race, slender, muscular, somewhat above the average height, but with no tendency toward fat, which is considered becoming only among the young girls of a few tribes. Their endurance of bodily exertion and privation is wonderful, but above all they excel in walking and running. The Berber couriers who carry the German mail in Morocco cover an incredible distance, as much as 120 kilometers in twenty-four hours. When my attendants traveled 40 to 45 kilometers on a stretch they showed not a trace of fatigue. They all love exercise. Unlike the indolent Arabs, they are very fond of playing ball, and have everywhere, as in our country, clubs for shooting, fencing, and the like.

The warlike tendency gives rise also to standing feuds among the different tribes. These feuds were formerly purposely encouraged

by the Government in Morocco, in order to weaken and subdue some of the tribes. They would deliver one tribe, with whom they could do nothing by fair means, over to another or several others to be "eaten up." These always carried out the commission as thoroughly as possible, so that the implacable hatred of the conquered people was rendered ineffective for a long time.

The Berbers are endowed with all the characteristics, physical and intellectual, which go to make superior soldiers: personal bravery, scorn of death, and sobriety. The French would before long have had all of them organized into a large army, but since by so doing a hostile force would be assembled, only a few thousand men were enrolled. Berbers form the principal part of the Tirailleur regiment. It is to be observed, however, that these physical characteristics, as well as the astonishing longevity which was noted even in the Roman inscriptions in the eastern Atlas region, are to be attributed to the fact that only the strongest by nature survive the lack of care during childhood.

The skin of the Berbers is light brown like the southern Europeans; their hair is usually brown, though frequently blond, and their eyes are blue. Their countenance is open, fearless, and intelligent, and their eyes full of life.

The Beni Mgild of the central Atlas region of Morocco are termed reddish blond by de Segonzac; the neighboring Aït Aiach are also usually blond and blue-eyed, according to him. The Fahcya around Tangier are mostly brown or blond with blue eyes, and Ch. Tissot maintains also that the blond element is most frequent among the Berbers of the Moroccan Atlas country, where they have retained the purest type. At least one-third of all the inhabitants there are blond. The same is true of the Berbers of Jurjura and of the Aures Mountains in Algeria.

Colonel Lartigue, who has made a comprehensive study of the Shauia of these mountains, says that they closely resemble Europeans and often have blond hair, although they are generally dark. They are wiry and thin and their average height is about 1.75 meters (5 feet 9 inches). Kobelt, the German physician and naturalist, asserts that among the Milianah west of Algiers half of the children have blond hair and blue eyes, and even among the adults there is a striking number of blonds or of those with light-brown hair. The Berbers of Jerba also are blond or have chestnut-brown hair. This characteristic is verified by the oldest extant set of sailing directions for the Mediterranean, the Stadiasmos, in the latter half of the third century A. D., where these Berbers are mentioned as blond and very handsome.

The famous poet Kallimachos, a Cyrenean Greek of the third century B. C., also tells of the light color of the indigenes of Cyrene,

while on the Egyptian monuments the Libyans and Tamahus are represented with European features and blond hair. When the Spaniards discovered the Canary Isles they found there a blond and brown type. That people have considered these blond Berbers as remnants of the Vandals may be merely mentioned.

The Berbers, in direct contrast to the Arabs, have a great ability for grasping ideas, especially practical ones, and have great capacity for work. Berber jugglers, often of remarkable dexterity, travel all over the world, and are known even in Germany, where some of them have served also as teachers of their language.

The Berber is passionate and easily moved, but at the same time serious, even sad. He has a great deal of personal pride, as I know from my own experience, and resents unkind and inconsiderate treatment, a fact that many Europeans seem to overlook. A Berber keeps his word. Their acquisitive instincts are highly developed, but their food and domestic arrangements are simple, even in great prosperity. Rich and poor alike wear the same soiled and tattered burnous. The Berbers value personal property highly. Many Berbers from south Tunis wander toward the city of Tunis, and many Berber mountain and oasis dwellers of Algeria travel to Algiers and other coast cities to save a little sum of money and then return to the home country, to which they cling faithfully, and buy a bit of land and a little house, the desire of every Berber. Thousands of them travel every year to Algeria to work on the railroads, at harvesting, on harbor works, in mines, and in other such places, in order to earn money. I have myself traveled with such groups for some time in the interior of the Moroccan Atlas foreland, to become familiar with their views and experiences. The Berbers are industrious agriculturalists and tree cultivators. In the mountains, where there is a local overpopulation—in Jurjura there are almost 100 people to the square kilometer—they have terraced the slopes and artificially irrigated and fertilized them in order to make the most possible out of their valuable ground. Every available foot of earth is made use of. In this way they have transformed several mountain districts into very landscape gardens; for example, the inclines and valleys of the Serhun, the sacred mountains near Fez, the slopes of the Atlas near Demnat and the Jurjura and Aures mountains of Algeria. In the Serhun the products of the olive and fig trees bring the necessary ready money, while in the other mountains apricot trees furnish this.

How valuable these irrigated garden lands can become in these comparatively thickly populated mountain districts is shown by the fact that in the Aures mountains a hectare is worth as much as 16,000 francs. The island of Jerba is one great garden and orchard. It is astonishing to see how the Berbers have been able to adapt to

cultivation the dry and rocky mountains of southern Tunis, especially in the territory of Arad south of Ghabes and of Tripoli.

Bee culture is carried on with especial zeal by them, and wax is therefore one of the exports of southern Morocco.

All the Berbers seem to have a leaning to a settled and agricultural life, although it must be admitted that those tribes which are known as seminomads or nomads only are cultivators from necessity. The Berbers are also clever artisans, masons, joiners, weavers, potters and the like.

Pottery and woolen weaving flourish in Jerba, and the purple-dye industry has been carried on there for a long time, while the woolen trade of Tunis is almost altogether in their hands. Tanning, dyeing, soap making, leather working and the like are carried on in other places. The Mozabites are especially skillful merchants.

From a moral point of view the Berbers show great contrasts. An authority has advanced the opinion that "pure Berbers have pure morals." The mountain Berbers of Rif and the Berbers who are the least mixed of all are recognized as especially strict morally. On the other hand, we are assured that there are many tribes with loose customs, who are of ancient descent, at least the oasis dwellers of the great deserts come in this category. * * * Wives are bought in some regions, yet in many tribes the position of the women is much freer than among the Arabs, as is shown by the fact that they go unveiled.

The Berbers have been altogether won over to Mohammedanism, yet that religion became generally known only in the sixteenth century, and was then only outwardly observed. The Berbers seldom exhibit religious fanaticism, least of all in Tunis. The Jebala drink wine which they make themselves, as well as buying it from Jews and Christians, so that drunkenness, unheard of elsewhere in the world of Islam, is not infrequent among them. They also smoke kif immoderately and eat boar meat. The saints' tombs, which are sometimes small cubical structures with domes called Marabut or Kubba, and sometimes mosque-like buildings, are always carefully covered with white paint, and therefore are visible for a great distance. These are very much reverenced, especially in Morocco, and are very numerous, while mosques are few. Sherifia families, who because they are descendants of the prophet are considered as holy and enjoy especial privileges, are frequently found and often form entire villages. These are of course Arabs. Occasionally especially prominent sherifs, i. e., descendants of Mohammed, succeed in making peace between tribes who are in blood feud with each other, and everywhere act as protective guides and make journeys through hostile territory possible. The only places I have experienced unfriendliness in my travels have been these sherif villages, for, dirty and ruined as these holy

places usually are, the Christian may not camp near one because he might defile it. Religious orders and sects play a great part in Berber life. Those of the Ma el Ainin in southern Morocco are very important at present.

The Berbers use the Mohammedan calendar in political, municipal, and religious affairs, while for the seasons of the agricultural year the Roman or Christian calendar is in use. The great agricultural feast of Ansera therefore falls on the summer solstice.

The agricultural calendar of the Moroccan Berbers, as well as that of the Fahçya, has the following months: Jenaïr, Febraïr, Mars, Ebril, Maio, Junio, Juliuz, Aghocht, or Ghocht, Chutembir, Octuber, Nuambir, Dudjambir. Even the Tuaregs of the desert still have this reckoning of time. The Shauia of the Aures Mountains, who still keep up many old, originally Christian customs, still celebrate Christmas under the name Bu Ini. The first day of the year is universally called Junâr (January). On this day all clothes are washed and all utensils in use changed. The new year's night is celebrated by a feast at which meat and eggs are eaten. Six weeks later, when spring begins, the people of Menaâ have a country feast, when they march into the woods to the sound of the flute and come back decorated with branches and herbs.

The Berbers are a thoroughly democratic folk, especially the mountain people. In this they differ fundamentally from the Arabs. The Jemaâ, a common council of the elder and more important men of the village or tribe, takes care of the local affairs. Every village has its common hall, Beït-es-Corfa, which often also serves for a magazine for weapons and gunpowder, as among the Jebala. In Jurjura the common hall is generally a simple stone structure with benches within, at the entrance of the village.

The consciousness of any racial connection seldom goes further than the tribe. There are a number of confederations, however, which prevent in a measure the eternal feuds between the tribes. As far as the French have carried their dominion they have put a stop to these feuds. The facilitation of travel for which they are responsible, and the activity of the widely distributed religious orders, has had the result, however, of making the widely separated tribes known to each other and of wakening and strengthening the idea of national unity among them. This condition will be of great importance in future events.

The settlements of the Berbers are consistent with the warlike nature of the people, to the prevailing insecurity and to the topographical conditions. These are always small villages, as is natural in an essentially agricultural population, and are known as Dchar (plural Dchur), Ksar (plural Ksur), and also as Dechera. Large settlements like cities are found only in the oases and in a few wide

and especially well-watered valleys. All the settlements, however, are inaccessible and fortress-like, perched on an incline or a cliff in a commanding position and visible from a distance. The little low stone dwellings are generally built in a circle with their backs abutting on each other, so that they may form the surrounding wall of the little fortress, which is entered by a single gate. Even the more recent villages of the Fahçya around Tangier are built on this plan and with this sort of construction. They consist of nothing but little high lying groups of tiny straw-covered houses or huts woven of twigs (Gurbi). Three of these generally form an enclosed court, and the whole village is surrounded by a circular or rectangular wall made up of the back of the houses or of a thick, impenetrable hedge of opuntias or cacti. It is the same way in the Berber mountain nests of central Tunis, Bargu, and Kessera. Among the Fahçya there generally stands in the plaza in the interior the one-storied white-tinted house of the Moqaddem or magistrate, generally the wealthiest man of the village. In front of this house, under the shade of a tree, the Jemaâ, or town council, is convened. Here also is situated the mosque, when present, generally nothing but a hut, where school is also held. It serves, too, as a sleeping place for Moslem guests.

I found the Berber villages in the plains of southern Morocco also built in a circle and fortified by an impenetrable wall of thorns (*Zizyphus Lotus* L.) with only one entrance, which was closed at night also by a gate of thorns. It would not be an easy thing to storm one of these fortresses. Sometimes the lay of the country does not allow such a construction; then the little houses and courts ascend the slopes or terraces like an amphitheater and are generally perched on top of as steep declivities as possible. This method of settlement has put the Berbers in a position peculiarly suited to perpetuate their language and customs. The Romans were never able to conquer Jurjura, the so-called greater Kabylia, and therefore named it "mons ferratus," and the French have succeeded in doing this only after twenty-seven years of hard struggle. The Morrocan Atlas and Rif mountain regions are one great fortress of this kind. It is to be further remarked that the mountain Berbers generally build strong castles with stone or mud walls to which they bring all their stores and valuables, each family having a separate room. These castles serve as a place of refuge in war times. All the heights on the edge of the high Atlas Mountains to the south and east of Marrakesh, especially in Demnat and Entifa, are crowned with such strongholds, resembling the ruined castles of Germany. These are called Tirremt. The strongholds in the upper Muluya region are like this also. They at once reminded me of the church fortresses of the

Transylvanian Germans, or the so-called Saxons, which were built for similar reasons.

These forts are encountered throughout the whole territory inhabited by the Berbers. In the Aures Mountains these joint fortified storehouses are known as Gelaâ or Thaqelet (fort). The village, which consists of low cubical houses of stone or air-dried brick, is generally built on the slopes around the Gelaâ. Many a Gelaâ can be entered only with the help of a rope ladder.

In the interior of central Tunis there are numerous flat-topped peaks which form natural fortifications and have invited settlement. These have there the same name, Kelaâ. The one best known is Kalaat-es-Senam, which dates from the Roman period, and in the later history of Tunis has been the center of the resistance to the Bey. It is accessible only by a stairway hewn in the rock. These fortified storehouses are met with in the greatest numbers in the southern Tunisian region of Arad on the serried mountainous cliff walls of the great desert plateau which runs eastward from the lesser Syrtis. Here are found real fortified cities like El Mudenin and Metamer, which form the storehouses of entire tribes and even confederations.

El Mudenin, the storehouse of 20,000 nomads of the pure Berber tribes of Urghemma, is inhabited in winter only by the guards and a few traders and innkeepers, when all the Berbers have led their herds far into the desert. From the inside, the six or seven storied houses seem like open honeycombs. They are nothing more than small arched rooms one above the other entered by pushing away a stone. Where possible these great storehouses are placed still higher on the cliffs and have a door only on the steepest side. The Berbers of this region, especially those of the tribe of Matmata, besides living in these mountain nests, also inhabit caves artificially excavated in the inclines of the valleys in the clayey marl which is sufficiently hard for the purpose. Quite a number of villages are made up entirely of these cave dwellings, so that they may almost be called Troglodyte mountains. A tunnel leads into a large, generally rectangular, court which is open at the top, and the dwellings and storerooms open into this like stalls. These regions, therefore, were practically independent of Tunis and were only conquered by the French in 1882. The Tunisian army with its cannon, which visited the region in 1876, had to withdraw from one of these mountain fortresses, Ksar Beni Knezer, as they found it impregnable. There are also cave villages in the Aures Mountains.

According to French statistics, of the 138,000 dwellings in Tunis in 1890, 57,000 were houses and 81,000 tents. I do not think, however, that in Algeria and still less in Morocco the number of tent dwellers is comparatively as great as in the open and generally level country of Tunis. The tent dwellers need not be all accounted as

pure nomads, for most of them may properly be ranked as semi-nomads. In any case, however, they are shifting and evasive. The tent villages of the seminomadic Berbers are also built in circular form, as indicated by their name, Duar. The cattle are driven into the circle each night, so that when I was among the Beni Ahsen of the Sebu plain of Morocco my tent, pitched inside the ring, on account of the predatory Zemmur, stood in the midst of herds of cattle.

The language of the Berbers, the Tamazirt, the preservation and spread of which has already been considered, has been too little investigated as yet. It is broken up into a number of dialects, as might be expected from the wide distribution of the people. The study of it makes comprehensible, however, the meaning of the few fragments of old Libyan inscriptions which have come down to us, for on Libyan monuments of the period are found script characters still used by the Berbers, especially in the alphabet of the Tuareg Hogar.

It is only since the Targi alphabet (Tifinagh) has been known that it has been possible to undertake in earnest the restoration work which began when the bilingual inscription of Thugga in Tunis was found. There is no doubt but that the present Berbers speak essentially the same language as their forefathers of the Roman period. The Libyan alphabet was then always used, but became obsolete in favor of the Arabic on account of Mohammedanism. Still it is assumed that there are old copies of the Koran in Berber characters among the Rif Berbers.

The total number of Berbers at the present time may be roughly estimated at from 12,000,000 to 15,000,000.

In the Atlas countries there must be differentiated from the Berbers not only the Arabs, but also the so-called Moors. Under this name are usually included all the Arabic-speaking city dwellers of these countries. This is a greatly mixed element of the population. The principal stock is without a doubt Berber, since even now Berber blood is being continually mixed with these "city Arabs," as they may be well called. The most varied collection of other components enters into the mixture, however. In ancient times there were the Phœnician and Roman colonists, then the Arabs and, especially since the fifteenth century, the so-called Andalusians, Mohammedan emigrants from Spain, who spoke Spanish to some extent and were very often engaged in piracy. This brought Europeans in great numbers from all the Mediterranean countries, many of whom were absorbed in the Mohammedan population, becoming renegades. Christian women and girls were also brought and put in the harems.

Immigrations of Jews into this territory also reached well back into the Roman period. In Cyrenaica in the beginning of the second

century A. D., they were planning to form a state of their own. Still more Jews followed in the train of the Arabs, and those returning from Spain spread themselves all over the country. They are commonly city dwellers here as elsewhere and are generally engaged in mercantile business or in money handling, but there are also many artisans among them. In Morocco they are limited as a rule to their own quarter of the city (the Mellah). Single Jewish families and small groups of them are found everywhere in the Atlas region, even in the innermost valleys of the Moroccan Atlas region. Most Moroccan caids have a "court Jew" for their money affairs. The Marquis de Segonzac even found fortified villages of Jewish people armed with weapons like their Arab and Berber neighbors. Their number in the whole Atlas region probably does not exceed 200,000, although they play an important part in the commerce of the country. Politically they are now very influential, because since their emancipation in Algeria they have become everywhere the exponents and carriers of French customs and language, a fact which has made them doubly hated by the natives.

The Greeks, one of the most powerful of all the Mediterranean peoples, are among the oldest races of Europe. They have held with wonderful tenacity to their ancient territory and to the principal features of their national characteristics, and have absorbed all foreign invaders. Whatever good and bad characteristics we see in the present Greeks are essentially those of the old Hellenes. The Greeks of to-day must be admired especially for their patriotism, their national pride, their desire for culture and their willingness to sacrifice themselves for these ideals. These are their sword and buckler in their struggle for national existence, and can not be valued too highly. It is these characteristics which in spite of their partizanship, their distrustfulness, and their superstition, have brought the country to a new prosperity economically, and have raised them again to the position of the center of the entire Grecian influence, the focus of economic and intellectual life, and the point of departure for European civilization for the whole Orient. This little country has accomplished this, too, not only without any loss whatever to other races, but with a continual gain by the incorporation of other less resistant races. The Greek influence is making great progress; it is very important in oriental political affairs to-day, and is likely to become even more so in the future.

Just as the Greeks are absorbing the Albanians, who wish themselves to be Greeks, so in the middle ages did they take in the Slavic tide. The Peloponnesus was called Sclavinia after these people for a long time. Italian and other Frankish components have also been incorporated, so that the Greeks must surely be termed a mixed race. Only in a few out of the way mountains like the Maina and

Tsakonia in the Peloponnesus and on a few islands can we find any pure descendants of the old Greeks, who are distinctly Greek in physical type. This is especially true of the women.

The culture force in the Greeks, however, is out of proportion to their numbers. Compulsory education is unnecessary among a people where lazy children after fifteen absences suffer the disgrace of being excluded from attendance at school.

In order to estimate fairly what the Greeks have accomplished in the last fifty or seventy-five years, we must take into account how long these people groaned under the Turkish lash, and also the fact that the struggle for freedom turned the country into a desert, and the people, it might almost be said, into a band of robbers. Even the language has been purified again. That the Greeks never retrogressed in culture as far as the Bulgarians, for example, is of course to be attributed somewhat to the nature of the country, which may best be termed a maritime mountain country. For this reason the Turks were never able to subdue the people completely and permanently. The Greeks always held connections over the sea with the Christian occident and its culture.

The sea stamps its characteristics on the Grecian landscape and upon its people. Their home is the sea-incised land of Greece and the shores of its archipelago, a section of the earth's surface almost as large as Germany, but with hardly a fourth of the land.

Everywhere in Asia Minor, from Cilicia and Cyprus to the Hellespont and the Balkan peninsula, in Thrace, Macedonia, Albania, everywhere, the Greeks cling to the coast. Greeks are the freighters of the whole Mediterranean eastward from Odessa to Alexandria and to the west to Trieste, Malta, and Marseilles. For this reason they were indispensable to the Bulgarians as well as the Turks. The fishermen of the eastern Mediterranean from Syria to Tunis are Greeks.

It is in Turkish territory in the adjoining part of Asia Minor that the Greeks are making especial progress. The Turks had everywhere taken the fertile land from them and made them the tenants of large Turkish landholders, but they have transformed the mountains and the poor ground into thickly settled garden tracts and have finally bought out the Turks in many cases. The number of their children is everywhere large, on account of their great domesticity and the purity of their home life, so that they have an incentive in this also for acquiring property and spreading out.

The younger generation presses toward the mainland, especially from the islands, which have made up their enormous losses in the fight for liberty and are again thickly settled. Some are even overpopulated, like Samos. Many Greeks seek their fortune

cities of Constantinople, Odessa, Smyrna, and Alexandria, and return home prosperous, to purchase a homestead.

The number of Greeks can be estimated at about 5,000,000. A small number, to be sure, but we must consider that in the entire Kingdom at the end of the war for independence there were only 600,000 men left, while to-day, with a somewhat extended area, it is inhabited by 2,500,000 men, and these 5,000,000 people, united by a national spirit and a love of country, mean a great deal more in the thinly-populated Orient than they do in western Europe. The Greeks are therefore a factor which will have to be reckoned with, as the annexation of Thessaly and Crete, which awaits only its formal consummation, shows.

Migration has added new members to the Mediterranean race family. Some have been developed by the fusion of immigrants and conquering peoples with the already greatly mixed primitive aborigines, whose Latinization had brought them to a higher plane of culture, and some by the invasion of new races from the outside, who wiped out their precursors or absorbed them and appropriated their territory. Thus were the Latin peoples of the northwestern Mediterranean developed; all have a considerable admixture of Germanic blood, Italians as well as French, Spaniards as well as Portuguese. The initial stirrings of the great whirlwind known as "the migration of nations," which led into the German invasion of the Mediterranean, were aroused in Central Asia. This whirlwind drew the southeast peninsula of Europe and the Atlas region into the turmoil of its wake, and worked at first great havoc on the old Mediterranean civilization, but afterwards brought a new flourishing period. In this whirlwind of migration the Teutons were followed by the Slavs and Bulgarians, and after these came the Mongolians and Turks, both from Central Asia. Finally the steppes of Arabia gave forth swarms of men over all hither Asia and the north coast of Africa, which were swept across to the northern shores of the Mediterranean and back again toward the east, only to be halted in their course by the power of the Franks on the battlefield of Tours.

Of the Latin races in the Mediterranean region proper about 34,000,000 are Italians (including Corsicans, Maltese, Nizzards, Tessinians, etc.), 2,500,000 are French, about 300,000 of whom are in Algeria and Morocco, 18,000,000 Spaniards, and 4,700,000 Portuguese. Besides these there are about 200,000 Zinzares and about 300,000 Rumanians in Servia, Bulgaria, and the Dobrudsha.

The Slavs on the southeast peninsula of Europe number about 10,000,000—5,000,000 each of Servians and Bulgarians. Of these two the Servians came from the northward and the Bulgarians from the northeast. Both of them had hardly shaken off the Turkish yoke when they became engaged in violent conflict over the Macedonian Slavs, a body of people whose ethnical position is yet to be determined.

It is fatal to the Servians that they, like the Albanians, are divided between the Roman Church, the Greek Church, and Mohammedanism. They are also hampered by being divided politically into two countries, Montenegro and Servia, and are also spread out into Dalmatia, Bosnia, and Herzegovina. It is also true that a considerable portion of old Servia is still under Turkish rule. Bulgaria, on the other hand, is almost a national unit, and only a small part of its people, the Pomaces, have gone over to Mohammedanism.

After the Slavic wave came the Arabic period of influence, which Arabicized not only Egypt and the northern part of Africa, but also Syria, which had become strongly Grecian, but in whose population the old Aramaic element was still strongly dominant. Mohammedanism stretched as a barrier across the whole Mediterranean region and was a great factor in causing uniformity of life and customs. This is to-day far less effective and broken down in many places, but is still a great influence.

During all these centuries this region became the region of greatest friction between occidental Christians and the oriental world of Islam. This region of friction became still larger when the steppes of Asia again poured forth a flood of people against the Mediterranean region and Europe. This time it was the Turks, followed by the Mongolians, who came with a rush and retired as quickly as they came, at least from Mediterranean territory.

The Turks, however, obtained a firm foothold in Asia Minor, cleared out the last trace of the Roman Empire of the east, and subdued almost the whole of southeastern Europe. It was only the German strength which stopped them there also, for they made themselves masters of almost the whole world of Islam, which had been till then entirely Arabic. Syria, Egypt, and the whole of north Africa as far as Morocco fell into their hands. Under Turkish rule all Christian civilizational influences were excluded even more than under the Arabs. Behind the boundaries of the Turks, Bulgarians and Servians reverted to barbarism, Albania became the least known of all European countries to-day, and Asia Minor, Syria, and all of northern Africa remained absolutely isolated and unknown.

Tunis has been opened to commerce only since 1881, Morocco only since 1900 in the principal lines, and the same is true of Tripoli and Barca. Since the beginning of the nineteenth century, in fact even since the eighteenth century, the Turkish tide has been on the ebb. Greece, Servia, and Bulgaria are again restored to the Christian world. Algeria belongs entirely to the French and Tunis essentially so, while Egypt has fallen to the English.

It can not be said, however, that the contrast between Christianity and Mohammedanism is any less for this reason. On the contrary,

it runs like an electric strain through the whole region and will make itself felt in every military development within its reach, especially in the Atlas countries and in Egypt, in a manner that will surprise the unknowing.

The Semitic and Mongol-like elements which the Arabic and Turkish invasion brought with them into the Mediterranean region were not of great importance, since the people themselves were not very numerous. But whether because of their despotism or whether because of the power of Mohammedanism, as we have seen in the case of the Berbers, they seem to have made the foreign elements conform to their habits. Therefore we can consider as "Arabs" not only the inhabitants of Barca and Marmarika, who are pure Arabs, only 300,000 strong, to be sure, but also the inhabitants of lower Egypt and Syria. But while the changes in the political map have caused no ethnical differences of any moment in the Arabic division of Mohammedanism, in the Turkish division these have been especially small. This is no doubt due principally to the fact that the Turks were represented in the greater part of their empire only by officials and soldiers who have disappeared again with the Turkish dominion. Thus there are no longer any Turks in Algeria, Tunis, or Egypt.

In Algeria even the Kuluglis, sons of Turks, have disappeared. The military colonies also, which especially in Greece, Servia, and Bulgaria kept guard over the important points on the great military routes which lead from Constantinople and Salonica through the peninsula to Belgrade, are to be seen no more. But not only the Turks themselves, but also the Tartars and Circassians, who settled under their protection in Bulgaria, have wandered back into Turkish territory, particularly to Asia Minor, where under the name of Muhadshir they have essentially strengthened the ranks of the Turks, especially in agricultural matters, since they are on a somewhat higher plane of civilization. By such remigrations the number of Turks in the part of the Balkan peninsula still controlled by them has become considerably increased, especially in Constantinople.

Nevertheless, if the number of Mohammedans in the southeastern part of Europe is set at 3,500,000, we could find hardly 1,500,000 Osmanlis among them, and these also, like the whole Turkish people, except, perhaps, the Turkomans of Asia Minor and the northern edge of Syria, who came in later, are so mixed with Aryan blood from the incorporation of the Janissaries, for instance (principally enslaved Christian boys of especial power), and are so confused by admixture with Persian, Slavic, Greek, and Circassian slave women that their physical type has lost every Mongol-like characteristic, even if they have preserved their own system of morals and their language.

The number of the Turks is considerably decreasing also in their own native country, Asia Minor. The principal reasons for this are that they alone bear the blood tax in their incessant wars, so that the young men are for many years withdrawn from home—in some vilayets the women outnumber the men by 12 per cent—coming back, either not at all or physically and morally injured, and that they suffer more commercially under the poor Turkish administration than do the crafty Greeks, Armenians, and others.

Figures show that the Turkish civilization in nearer Asia Minor has been almost supplanted by the Grecian. This fact also is likely to have important political significance in the near future. The number of Osmanlic Turks and those who consider themselves such is very difficult to estimate. Ten millions would probably cover all. Besides "Turks" and Greeks, there are a few hundred thousand Armenians in Asia Minor who were distributed forcibly by the Turks all over the peninsula even as far as Constantinople.

The Arabic-speaking population of Syria, a considerable part of which is Christian, however, may be estimated at 2,000,000 and that of lower Egypt at about 5,500,000.

Neglecting small and from our point of view unimportant divisions, we get in round numbers the following table of the apportionment of races of the Mediterranean region:

1. Catholic Latin peoples on the bays of the northwestern part		60,000,000
(*a*) Italians	34,000,000	
(*b*) Spaniards	18,000,000	
(*c*) Portuguese	4,700,000	
(*d*) French	2,800,000	
2. Slavs of the southeast European peninsula (Christians of the Greek Church)		10,000,000
(*a*) Servians	5,000,000	
(*b*) Bulgarians	5,000,000	
3. Albanians (Mohammedans, Roman Catholics, Greeks, Christians)		1,500,000
4. Greeks		5,000,000
5. "Turks"		10,000,000
6. Berbers		13,000,000
7. "Arabs"		8,250,000
Total Mohammedans		31,000,000
Total Christians		75,000,000
Grand total of all Mediterranean peoples		106,000,000

From this it appears that the Christian inhabitants of the region are in the great majority. It also appears that the Mohammedan districts are extremely thinly populated. This is due not so much to geographical disadvantages, for Syria, Barca, Tripoli, and Tunis

were thickly populated in the Roman period, as to the poor administration, which marks all Mohammedan countries. Egypt, Tunis, and Algeria all show that such countries under European and Christian administration rise quickly, economically, and increase in population.

The superiority of the Christian people over the Mohammedans in the Mediterranean region, although it must be discounted somewhat by the clannishness of these latter due to their religion, is heightened by the fact that the followers of Islam inhabit even to the present day the dryest districts on the Mediterranean and are all landsmen and have an aversion to the water, Turks as well as Arabs. The Greeks, Italians, and the other Christian peoples tend entirely to the sea traffic. The Turks have never had any knowledge of maritime lore and to this day are ignorant of it. In those periods when there was a powerful Turkish fleet, the ships were commanded by renegades and manned by Christians. The Barbary pirates were "Andalusians" driven out of Spain, and Berbers, and their leaders in the sixteenth century were mostly renegades also.

The last and most important indication of the table is that, of the 106,000,000 inhabitants of the Mediterranean countries, 34,000,000, or 32 per cent, are Italians. This is a highly important fact and one to be well considered in the near future, for the national unity of the Italians, which has resulted in great economic development, will make itself felt with growing political importance and render active the advantages of central position and other geographical factors. This is all the more likely because the characteristic tendency of pushing toward the sea and centralization on the coast, which marks the distribution of all the Mediterranean peoples, is especially pronounced in Italy.

Italy must naturally be a thoroughly maritime country from its long and slender shape, for its extension across from the foot of the Alps almost to the Atlas Mountains furnishes long coast lines and slight distances from the sea. The people there press toward the sea, a fact which is most marked in Liguria, Apulia, and in the north and east coasts of Sicily. All the larger cities lie on the seacoast; even Milan is only 120 kilometers (75 miles) from the ocean. Eighty per cent of the surface of the kingdom is within 100 kilometers (62 miles) from the sea; that is, in two hours one can reach the sea from any part of this country. Fully 16 per cent of the population live directly on the ocean. This is a fact of great importance for the prestige of Italy in the Mediterranean. The Italians have been skilled sailors from time immemorial and the fisheries of the Mediterranean are for the most part in their control.

Likewise in almost all the other countries on the Mediterranean the people live principally near the sea. In Spain there has recently developed a sharp contrast between the interior and coast provinces;

the population in the former is steadily decreasing, while in the coast countries it is just as steadily on the increase.

From the very small number of 35 inhabitants to the square kilometer, the interior provinces have decreased to 14 and 15, while in the Mediterranean coast provinces Valencia shows 68 to the square kilometer, Malaga 71, Alicante 76, and Barcelona 117, as much as the average of the whole German Empire.

In the Atlas countries this tendency toward the sea is even more marked; all the larger cities lie on the coast, Constantine and Tlemcen are less than 100 kilometers away, and this distance is only exceeded in the cases of Fez and Marrakesch.

We may safely say that two-thirds of all the inhabitants live less than 100 kilometers from the sea. It is the same way in Syria, where the deserts begin less than 100 kilometers from the coast, and the case is the same in Asia Minor and of course in Greece and the Balkan Peninsula.

This brings us to the conclusion that all the Mediterranean countries were thickly populated in ancient times and have not changed so in their nature that they could not support a far greater number of people than they do to-day. Asia Minor alone, where to-day there are only 18 inhabitants to the square kilometer, has room for forty-three millions more, while the girdle of land which begins at the gates of Vienna and ends at the mouth of the Euphrates could surely hold a hundred millions more. If we consider this and the fact that in the Mohammedan countries which are under European administration the population is again increasing, as is shown by Egypt and Algeria, it becomes very evident that the Mediterranean not only looks back on an illustrious past, but is destined to have a great future, and its political importance will become steadily and rapidly greater as time goes on.

PREHISTORIC JAPAN.[a]

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As an introduction to the subject of this paper, which concerns the history of primitive Japan as developed from archeological finds, it seems proper briefly to review the types of men now living there and to sketch their origin.

At the outset we may safely affirm that all the race types of which we find remains or traces are represented among the Japanese people of to-day. It is a fact that within the last 2,000 years no conquering peoples have invaded the borders of Japan. Even earlier than that it is probable that only very few large and powerful influxes occurred at any time on account of the position of the country in the midst of a sea where storms and currents prevail. Since the beginning of our records immigration has come solely from the neighboring countries, China and Korea, and for more than a thousand years even this has been too insignificant to be worthy of consideration.

In previous addresses before the German Anthropological Congress in 1885 and five years ago before this society I have considered the eastern Asiatic race peculiarities in detail and have distinguished in Japan three essential elements: First, the north or true Mongolian type; second, the south Mongolian or Malayan type, and third, the Aino type, which is at present becoming less and less frequent. The Ainos were the original inhabitants, but for practical reasons I shall consider them last.

It is hardly possible to draw a sharp line between the Malayan and Mongolian types, as the transition from one to the other all over eastern Asia is so gradual that every attempt to make an exact division has failed. For example, we find in Japan, Korea, and China a large number of people who might be termed pure Malays, and, on the

[a] Translated, by permission, from Zeitschrift für Ethnologie, Berlin, 1907, part 3, pages 281–310. Read at the meeting of the Anthropological Society of Berlin, May 19, 1906.

other hand, in southeast Asia we may find the most marked slant-eyed Mongolian type, of which the present nominal Emperor of Annam is a good example.

For these reasons the term Austrasian (i. e., eastern Asiatic) race is preferable to the expression "yellow race" used by Cuvier for the combined Mongolian-Malayan races, as it includes people of a dark-brown color in the southern part of the Asiatic continent.

So much can be said, however, that the north or true Mongolian division may be distinguished by their comparatively large size, large head, prominent cheek bones, more or less slanted eyes and meso- or brachycephalic skull, while in the southern or Malay division, smaller size, less prominent cheek bones, and less slanted or more horizontal eyes prevail. Probably there is an admixture of Hindu or other foreign blood in many "Malays."

In Japan these types are seldom found pure; much oftener they are mixed.

The assertion that the Japanese are essentially identical in race with the inhabitants of Korea and the larger part of China was formerly strongly combated. Investigators were too much influenced by outward appearances, especially by dress and methods of wearing the hair. Even such a keen and much traveled observer as Lord Curzon, late viceroy of India, allowed himself to be led astray. He declared that the Koreans were such a characteristic race that it was impossible to confound them with the indigenes of another land wherever they might be met. To contradict this I have the testimony of any number of Japanese and Koreans, that they themselves can not distinguish one from the other if costume and method of hairdressing are the same; and in comparing Japanese and Chinese, the same holds good. Even conceding that the Chinese are generally larger and have softer features, the difference is hardly greater or even as great as between different types in Germany, or between the English and Germans. Therefore I can not understand how Dönitz[a] can say "the Japanese are so different at first sight from the Mongolians who inhabit the neighboring mainland that it is hard to conceive how there could be any direct connection between them." Clearly he, too, had been deceived by outward appearance, especially by the difference of clothing and hairdressing. The sight of Koreans in European dress would soon have changed his opinion.

The natural path for immigration into Japan is through Korea, as a glance at the map shows. This is confirmed by the most ancient traditions of Japan and the finds of the prehistoric period. By this route the people entered who first brought a sort of civilization into

[a] Vorgeschichtliche Gräber in Japan, Verhandl. d. Berl. Anthropol. Ges. 1887, p. 114.

the land. They landed on the island of Kiushiu and on the southerly part of the west coast of the principal island, founding a kingdom in Idzumo, the oldest of which any Japanese sources speak. The accounts of this kingdom are mythical, or legendary. Gods, monsters, and miracles play a great part in them, but without doubt there is some historical truth at the bottom. Another early migration of well organized but less civilized people must have been directed to the central part of Japan in the region around Kioto and Nara, which was afterwards the true center of the Japanese Empire for two thousand years.

Probably later than these immigrants came other tribes, either by way of Korea or along the chain of islands made up by Formosa and the Liukiu Archipelago, which joins South China and Japan. The latter route, to be sure, is longer, but it is made comparatively easy by the "Kuroshiwo" or the "black current" which flows in this direction, and by the periodic southwest monsoon of the summer which drives vessels northward, and the northeast monsoon of the winter which enables them to return easily. Whence the wanderers came who traveled by this route—if they did come this way—we do not know. Whether it was from Formosa, or, what is far more likely, from Shantung, or parts of central or southerly China, is an unanswered question. We do know, however, that it is in the southwest part of Japan, where the Kuroshiwo skirts the land, that the so-called Malayan type is most prevalent.

These immigrations, particularly the last one, in all probability occurred in the first thousand years before Christ. That they came from the mainland of Asia is further indicated by the otherwise unexplained appearance at that time in southwest Japan of an iron-age culture too high for Malays of that period. Furthermore, the Japanese language is related to the Turkish, Hungarian, and Finnish; that is to say, to languages spoken by people who had settled in central and eastern Asia. The Turks or, let us say, the peoples of the Turk race, in earlier times made themselves felt more in the east than in the west. Once they invaded Korea with a great army, an attack in which their whole army was annihilated. China also suffered much from their inroads. In the eighth and ninth centuries A. D. they held control of a mighty kingdom in Turkestan. When these facts are considered, the great distance between the present-day Turkey and Japan makes this relationship of speech less strange.

Even before immigration began by way of Korea or from the south, Japan was inhabited by people belonging to an entirely different race, the Ainos, little of whose blood remains in the veins of the Japanese at the present day. Once, as the names of mountains, rivers, and other localities bear witness and archeological finds indicate, they inhabited the whole of the Japanese islands. During the p

recorded by history they were driven from the northern half of the main island toward the north, till they remained as a pure race only in the island of Yezo. Therefore the Aino type is met more and more frequently in the north of the main island as we approach Yezo, but even in the center of the island scattered remnants are still found. I have been repeatedly surprised at the number of individuals of the pure Aino type that dwell in the barely accessible mountains of the three provinces of Kodzuke, Shinano, and Etchigo. Apparently the uncivilized Ainos, pressed hard by the advancing Japanese, fled hither from all the surrounding territory. In the famous watering place Kusatsu, lying in this region, where the same families have persisted for many centuries without new infusion of blood from the outside, I have seen examples of the most pronounced Aino type.

According to my hypothesis those of the inhabitants of Kiushiu and the Liukiu Islands who are characterized by their thickset build, more or less European cast of countenance, and heavy growth of hair, are also to be classed as the remnants of this or a cognate primitive people. These are the groups designated as Kumaso and Hayabito in the Japanese legends and the oldest historical records.

The intruding Mongolian conquerors first took possession of the plains and the fertile coast region, forcing the aborigines toward the north and toward the wild southeastern region into Kiushiu and the Liukiu Islands, or perhaps sparing them only in these regions. For only in these last-mentioned districts do we find this type at all frequent. It is generally admitted to-day that the Aino is not Mongolian, but is closely related to the Caucasian race. It is difficult to understand how anyone who has seen a large number of pure Ainos could believe them Mongolians.

They now number about 17,000 on the island of Yezo. On Sakhalin they are still fewer. They will soon disappear as a race, not, however, because they will be stamped out by the encroaching civilization, but because they will be gradually absorbed by the Japanese. Intermarriage is now of almost daily occurrence, and the opinion of Mr. B. H. Chamberlain that such marriages are barren is not borne out by the facts. I have myself seen many offspring from such unions. The Japanese type generally prevails amongst these half-breeds.

From what land the Ainos came to Japan we have no idea. We are much more at sea than with those people of antiquity about whom Schiller could say, "Würde die Geschichte davon schweigen, Tausend Steine würden redend zeugen, die man aus dem Schoss der Erde gräbt;" for the Ainos have neither any art nor a written language.

The common hypothesis is that they came by way of Sakhalin, which at a recent period, geologically speaking, was continuous with the mainland and had probably a much milder climate before the formation of Bering Straits. But it is not necessary to go as far as

Sakhalin to meet the possibility of a dry-shod immigration from the mainland.

From the geological history of the British Isles we know the fact that not merely once but twice they were connected with the continent and twice separated from it. The sea floor sank and rose and fell again from 150 to 200 meters. In the Paleolithic age there was no English Channel.

Now, if the sea floor between Korea and Japan lay only 130 meters higher than it does to-day, Japan would cease to be an island. It would be an extension of the continent upon which the people of the Paleolithic and Neolithic ages, even unversed in maritime enterprise, could wander dry-shod. The whole Liukiu chain, too, would have been connected with Japan, and there also we find Aino-like hairy men, whose women folk tattoo their hands just as do the Aino women.

A less widely accepted theory is that the Ainos are related to the primitive inhabitants of Australia. This is founded on the actual resemblance often noted of the two types. On the other hand, there are essential differences.

Now the question is, were the Ainos really the first settlers in Japan or was there another people before them? This latter opinion has several supporters, being vigorously upheld by Mr. J. Tsuboi, professor of anthropology at the University of Tokyo.

In ancient Japanese tales and legends mention is frequently made of the so-called Tsuchigumo—that is, earthspiders or cave dwellers. On the other hand, the Ainos myths tell us of Koropokguru, and also of Kobito or dwarfs. The first is an Aino word, the second a Japanese word adopted by the Ainos. Koropokguru is commonly construed to mean men who lived beneath a certain sort of burdock with enormous leaves (*Petasites japonicus*), and who were therefore very small. But, in the first place, these burdocks grew so large in Yezo that a big man could stand beneath them, and in the second place, according to Batchelor, the highest authority on the Aino language. the word Koropokguru means nothing more than earth dweller, and consequently applies only to the inhabitants of the dwellings known to the Kurile Ainos to this day. It can not therefore be taken as evidence of the existence of a dwarfish race before the Aino.

This is very important, for it concerns the question as to whether the shell heaps found in great numbers all over Japan, with their rich contents of stone implements, pottery, human figures of clay, bones, and the like, are relics of the Ainos or whether they come from a still earlier people who might be considered to have been Koropokguru.

The afore-mentioned missionary, Mr. Batchelor, who lived f thirty years among the Ainos and devoted his life to teaching studying them, rejects the Koropokguru hypothesis as entirely

tenable from his wide experience. Professor Koganei, of the University of Tokyo, rejects it on anatomical grounds. On the other hand, Professor Tsuboi gives a long list of reasons that make it probable to him that the stone age and shell heap deposits originated from a people different from the Aino.

Most of Tsuboi's arguments are hardly convincing, but it is indeed a noticeable fact that the clay statues of that period do not have distinctly Aino-like features and generally have no beard. Tsuboi formerly held that none of them have beards, but recently has admitted that there are exceptions. He holds to the idea that a people resembling the Eskimos were the makers of these relics, and goes on to mention objects common to the stone-age people and the Eskimos, such as snow spectacles, clay vessels (the present Ainos in Yezo make no pottery), and various unimportant details like form of dress. But according to their own traditions the Ainos did make pottery at an earlier period and we find to-day among the Kurile Ainos the same sort of clay ware as the stone-age people made. Furthermore, clothing, the manner of hair dressing and head ornaments may have changed both among the Ainos and the Eskimos in the course of time. The conception of the rings around the eyes as indicating snow spectacles seems to me rather farfetched. Neither do the clay figures have such heavy clothing as must be expected if the stone-age people of Japan had lived in a climate like that of the present Eskimos. However, I hold to the idea that the Ainos were the makers of these stone-age remains with less certainty than do Koganei and Batchelor, on account of the type of face on the clay figures and the frequent lack of the full beard. Nevertheless these authors have by far the greater probability on their side.

Even if Tsuboi were correct in saying that the stone-age men were a people with little beard and far removed from the Ainos—in fact, if they were truly Eskimos—this would not exclude them from relationship with the present Japanese, for, in spite of their dolichocephalic skulls, the Eskimos stand very close to the north Mongolians.

So much for the race elements entering into the question.

As in most other countries, there are in Japan cave dwellings, sometimes single, sometimes in groups, but the archeological finds in these, as a rule, amount to nothing. The caves are almost all artificial and consist sometimes of a single low room of irregular shape entered through a hole, and sometimes of several communicating chambers at different levels. A cave of 15 square meters floor surface is about the limit in size. The people often call them "devils' caves." I have myself seen some such caves near Tokyo and have found nothing in them. At one place in the province of Kodzuke north of Tokyo there is a large hill honeycombed with these caves, which Professor Tsuboi has described in detail, but here also, all evidence is lacking as

to the period and peculiarities of the inhabitants. Perhaps they belonged to the cave dwellers or "earth spiders" mentioned in connection with the victorious marches of the first (legendary) emperor of Japan, Djimutenno.

In later times the caves often served as places of refuge for robbers and fugitives, and it is not at all improbable that during the endless civil wars that raged in Japan in the middle ages many such caves were made as hiding places by vanquished refugees. They are dug in a very soft sandstone easily scratched with the finger nail, and from their position in the wooded foothills of the mountains their origin might at least partly be attributed to such a contingency.

The theory has also been put forward that the caves were catacombs. But even the discovery of skeletons in such caves would not prove that they were the most primitive form of graves, for we know from the history of the Egyptians that they resorted to cave burials only after having erected the most artistic tombs in the open air for thousands of years. In fact, in Japan the rock graves, which occur in the southwestern and middle part of Japan surely belong to a higher period of culture, the iron age. Besides, even in our own time many inhabitants of Tonkin built themselves cave dwellings which could easily be confused with catacombs, although only a generation before they had lived in houses like their neighbors. These modern cave builders were Tonkinese and Chinese irregular troops, called pirates by the French. They dug caves in almost inaccessible cliffs to escape their European enemies. Perhaps in the next decade some learned investigator finding these caves will advance very profound theories about the aborigines of Tonkin. Let us therefore be cautious.

Everywhere in Japan there are shell heaps and other relics of the stone age which give a rich return, and which, as already mentioned, have led to a spirited discussion as to the race of their originators. The first shell heap was found and thoroughly investigated by the zoologist, Professor Morse, in the environs of Tokyo in 1879. The finds were described by him as numerous stone and bone implements, animal and human bones, mollusk shells, and pottery. Most of them are at present in the Imperial Museum at Tokyo. To-day the number of shell heaps and other stone-age sites known in Japan amounts to four thousand.

Even in the very outskirts of Tokyo some have been found, and near the city of Yokohama, close by the race course, I have myself collected a great number of primitive stone implements and pottery. Most of the implements consisted of roughly worked slate. There are among them, however, some well-finished stone celts, so that from the form alone we could draw no division line between paleolithic and neolithic. But, judging from the pottery, this whole culture is neolithic. Less frequently one finds well-fashioned arrow points,

lance points, knives, and other implements of flint or of obsidian. The quantity of stone implements varies greatly. In some shell heaps they are exceedingly numerous, in others one wonders at their scarcity. Most of the rough tools and weapons are made from the volcanic rock of the neighboring region; others are fashioned from serpentine, granite, gneiss, or other stone. Nephrite is very rarely used. Generally speaking the discoveries of stone weapons of fine workmanship become more frequent as we go north, because the stone age prevailed there long after the more civilized southwest had passed into the iron age. Evidently, however, stone clubs were used in that more civilized region too, for to the first Japanese emperor—supposed to have lived about the seventh century B. C.—is attributed in the oldest legends a song in which he says that he had struck down his enemies with his knobbed stone sword. There are

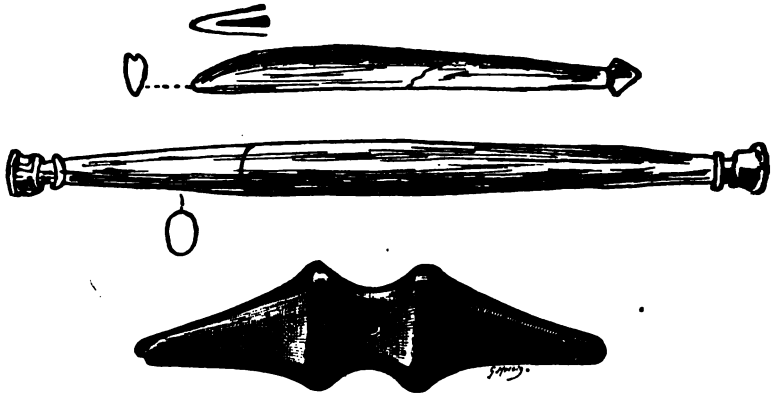


FIG. 1.—Stone weapons. Above a fragment of a stone club (or a commando staff?), which might be restored like the specimen beneath it. Below a beautifully polished pierced double axe.

many specimens of stone clubs, up to 80 cm. and over in length. Some of them are of a distinctly phallic shape.

As has already been stated, the roughly shaped tools form the great majority of the finds. The beautifully polished stone axes occasionally found often taper so little toward the handle that they appear almost rectangular and not trapezoidal in shape. They also occur with one beveled edge like the knife of a plane. Sometimes double axes are found with bored or unbored shaft. (Fig. 1.) Grindstones and the familiar stones with many small pit-like hollows are not common. Net sinkers and whirls are numerous, as is natural from the location of the shell heaps near the sea. The best examples of the pottery of the stone age are also found in northern Japan. It is here, too, where we find most frequently the highly characteristic statuettes of clay. Some of these are of a soft-baked gray clay mixed with animal hair; others are of a better red or black clay. The softness of

NEOLITHIC JAPANESE CLAY FIGURES, BAELZ COLLECTION. ONE-THIRD NATURAL SIZE.

Figures 1 and 2 have beards. They are made of a soft, poorly baked gray clay. Fig. 3 (feminine) is of black clay, but better baked. Fig. 4 is of terra-cotta color, thin walled and well baked. Its features recall the Japanese Haniwa figures of the dolmen age, which probably were known to the potter.

the gray figures is responsible for the fact that in spite of all care they do not keep in the same good condition in which they are found. Two of these gray figures, shown on pl. 1, have a full beard. They are the only ones of this sort known; usually the beard is absent or is only indicated by strokes of the modeling tool.

The eyes of the figures are often surrounded by a raised line which is construed to represent snow spectacles by some Japanese archeologists. A further thing to be noticed about the eyes is that they do not slant upward like those of Mongolians, but the lids are horizontal and the eyes are deep set like those of Europeans. Many of the figures are distinctly painted or tattooed on the face.

The gray figures are evidently the most ancient. The better burnt red and black figures are more recent, and some have the type of the Japanese terra-cotta figures of the iron age to be mentioned later, and have slit eyes and the aquiline nose of refined Mongolian type. Their entire workmanship and the care often expended on the clothing indicates a late period, perhaps the first centuries A. D. A few rather good mask-like representations of human faces have also been found.

The numerous handmade clay vessels and pots from the stone age show great variety in form and motive of decoration. They are made generally of a reddish clay and are often very badly fired. As they are usually thin, they break and fall to pieces easily, so that well-preserved pots of large size are rare.

Fig. 2 shows a collection of fragments with different patterns.

The most beautiful and best preserved vessels are found in the northern part, where for the longest period the stone age prevailed. They are sometimes red, sometimes brown, sometimes black, and occasionally gray. Some resemble glazed ware. Most of them are about the size and shape of a modern teapot and have often peculiar forms of spout and lid. (See fig. 3.)

The peculiar rectangular oblong or trapezoidal earthenware tablets should also be mentioned. These are sometimes as large as the hand, and are often decorated with human faces or eyes, or with other more or less fantastic designs. They are supposed to be toys or dolls, on what grounds I am not able to determine. More probably they were charms or idols.

Animal figures are few and small. Bear and bird heads are found, and occasionally fish heads.

Personal ornaments appear in the shape of stone and clay rings, hollow clay tubes, beads of bone and clay, and also the numerous comma-shaped objects 2 to 5 cm. in length, or even longer, which are called magatama (crooked jewels), and which were the most desired and prized personal adornments in Japan well into the his-

FIG. 2.—Neolithic Japanese pottery mostly from the environs of Yokohama. No. 17 has a script-like decoration. Nos. 8, 16, and 18 have patterns like the Yayoi ware which is attributed to a later period. One-third natural size. Baelz collection.

torical period. In the shell heaps they are of stone, horn, boar or wolf teeth, and in the graves of the iron age of glass, carnelian, rock crystal, quartz, and nephrite. They are generally perforated at the thick end and were worn on a string, together with beads and

FIG. 3.—Finer and more recent ware from northern Japan. The vase on the upper left hand is one-sixth natural size, the others one-half. Baelz collection.

bugles of the same material, as a necklace. Their peculiar shape has given rise to many conjectures. Probably they were originally teeth or claws of wild animals, which were worn as amulets everywhere in the stone age.

I show (fig. 4) for comparison a picture of the canine tooth of a wolf (now in the British Museum) from the French paleolithic caves of Laugerie Basse and an animal tooth from a shell heap in Japan. The figures called *c* and *d* are magatama of serpentine or rock crystal from Japanese graves of the iron age. The last form is the most frequent, and it is this form which is commonly meant when magatama are mentioned.

Dönitz thinks that the shape of the magatama indicates a "symbol of lascivious meaning." Others see in it a picture of the wing of a certain butterfly. Sometimes they look like a little fish. My opinion is that originally they were used as charms, either to protect the wearer from the animals from which they came or, in the case of the fish-shaped ones, to attract the fish.

Some special power must have been attributed to them, for their value as ornaments alone does not explain why they were used in

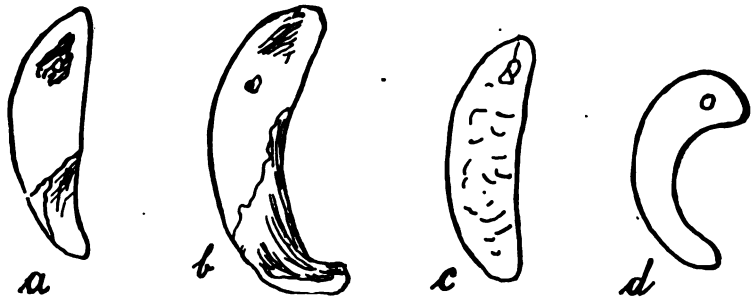


FIG. 4.—So-called Magatama, natural size. *a* is an animal's tooth from Laugerie Basse, in France (paleolithic); *b* is from a Japanese shell heap; *c* and *d* are from the graves of the Japanese iron age (Dolmen period).

mythical or half mythical times as jewels of the gods, of the Emperor, and of other persons of the highest rank. A magatama is even to-day one of the three emblems of sovereignty in Japan. Their religious significance can be seen also from their use in the Shinto ritual and from the further fact that two or three such comma-like figures forming a circle appear frequently on religious and ritualistic objects all over eastern Asia. The circle, made up of two "commas," one red and the other green, is the national emblem of Korea. This form represents the masculine and feminine principles—Yang and Yin of the Chinese—and also heaven and earth. The triply divided circle represents heaven, earth, and man (the product of the two). The Swastika, in my opinion, belongs to the same group of ideas.

Horn and bone are found as implements, such as needles, awls, arrow points, harpoons, pipes, and also, but much less frequently, fashioned into ornaments. The bones occurring most commonly are from deer and wild boars, and occasionally from dogs, wolves, and

monkeys. Among the monkeys Professor Morse has recognized a Kynopithecus besides the Macacus found in Japan to-day.

Human bones are found in the shape of fragments of tubular bones, such as the humerus, radius, ulna, femur, tibia, and fibula. Sometimes they are in a condition which points to cannibalism. Only incomplete fragments of cranial and face bones have been discovered.[a] The tibia are very flat, and in this respect the people of the shell-heap period closely resemble the Aino.

The shells of mollusks are naturally found in large quantities. Sixty species have already been determined, which, as might be expected, are distributed in varying numbers in different places. In this connection Morse's observation, that the mollusk fauna of Tokyo Bay has undergone a decided change since the building of the shell heaps, is of especial interest, as it indicates that these are very old. Professor Milne is bold enough to name a definite age—three thousand years. But it must not be forgotten that the bay of Tokyo has changed very much. The whole eastern coast of Japan in that vicinity is slowly rising. A large part of the area of the present city of Tokyo lay under water a thousand years ago, and the hill of Ueno, with its celebrated city park, was an island five hundred years ago. The great inflowing rivers have partly filled up the bay at the north end where the shell heaps examined by Morse lay. Therefore it is quite possible that the smaller percentage of salt in the water and other conditions altered the form, size, and frequency of the conchylia within a comparatively short period of time.

While the remains of the stone age lie scattered promiscuously around in shell heaps, and while no regular graves of that period are known, it is different in the metal age. This period may be divided into two parts, a bronze and an iron age (there has been no distinct copper age in Japan), but while in other countries we often find transitions from stone to bronze and from bronze to iron, the deposits of these three periods in Japan lie unmixed side by side, or one lies on top of the other.

That the people of the metal period were different from those of the stone age is evidenced by this lack of transition and by the distribution of the metal finds. These cease to the northward of Tokyo somewhat beyond the Kwanto Plain just where the region of the Aino began in historic times, and where the stone weapons and the corresponding pottery reached their highest development.

[a] Since the above has been written Doctor Munro, of Yokohama, the distinguished archeologist, has succeeded in exhuming six skulls of the stone age which in my opinion leave no doubt that the stone-age people were really Ainos.—E. B.

Tombs containing iron have never been found in this Aino territory, and stone weapons never occur in the graves containing metal.

The real question is whether the bronze-using people are identical in race with the iron people. Even if they are, we must assume that there were two distinct surges of immigration separated by a considerable period of time, the first consisting of people in the bronze age and the second of people in the iron age. The latter immigrants became the masters of the land, and the dolmen graves belonging to them were built even into the historical period. Their sway represents the dawn of twilight of history. There is no doubt but that the iron-age people were the direct forebears of the present Japanese.

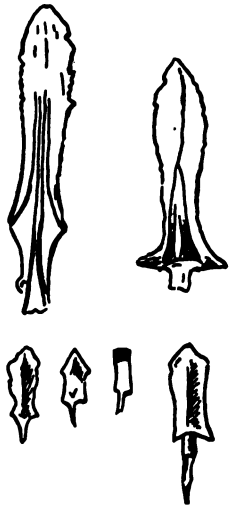


FIG. 5.—Japanese bronze weapons (after Gowland). Above swords or lances, the larger 70 cm. in length. Below, arrow points.

The difference of the bronze and iron age folk appears further probable from the fact that in the oldest Japanese annals (712 and 720 A. D.) the word bronze is altogether absent, unless possibly the word for copper includes bronze. In any case the annals consider iron as the only metal used in swords from the very beginning. Even the sun goddess has an iron sword. The bronze swords discovered must therefore come from another people or tribe, though the race in both cases may have been the same.

That both the bronze and iron people brought their culture from the continent is shown not only by the geographical position of the country and the indications of ancient legends, but also by the nature of the grave deposits.

The bronze age can be disposed of in a few words, for comparatively little is known about it. There are no distinct graves of this period, although bronze weapons and other implements often occur near the surface in fields or clearings of southwestern Japan. Together with them are sometimes found unglazed hand-fashioned cups and bowls of red clay. The bronze swords and lances are double edged, and they are similar to those of the bronze age in Europe. They are often so large that they were perhaps intended for sacrificial purposes rather than for use against enemies. Both these weapons and the rather infrequent arrow points are well finished. The latter are found in the iron-age tombs, whereas the swords of the bronze and iron ages are totally different.

Celts, needles, and fibulæ are not found in Japan. In plowing their fields, peasants occasionally unearth, besides little round bells, very peculiar large flat bells, made of thin bronze, as much as 80 cm. or

more in height. That these were intended to be hung up is shown by the hole at their top, but what they were used for and where they came from no one knows. They are generally attributed to Chinese origin. They show finely worked geometrical designs and often quite a number are found together.

The bells occur only in the vicinity of bronze weapons in southern Japan, especially in the part lying nearest the continent. The farther north the less frequently do bronze articles occur, and on the northern side of the inland sea there are none.

Although there can be no doubt but that bronze weapons were cast in Japan, molds for casting swords having been found, it is doubtful whether the bronze itself came from Japan. Several Japanese archeologists think that all bronze was imported from China or Korea. In early times neither copper nor tin mines were known in Japan, and when the first copper mine was discovered there about 700 A. D. it was considered an occasion for national celebration; and yet the bronze age must have antedated this by at least 1,500 years.

Few ornaments of the bronze age are extant. They are principally beads, bugles, or magatama, made of rock-crystal, steatite, and jasper. Unfortunately all discoveries of the deposits of the bronze age were made by accident and by uneducated people, so that a systematic consideration of them is out of the question. The theory is that the places where the bronze pieces are found were originally graves, probably covered by a small tumulus which gradually wore down or was destroyed by the farmer. Whether or not they inclosed sarcophagi of wood or of soft terra cotta can not be determined. If there were any, they have been totally destroyed by the weathering, as have the bones of the persons buried. Anything like a stone lining has never been found.

The iron age in Japan is at the same time the dolmen age. W. Dönitz has described the dolmens in the volume of 1887, page 114, of these Proceedings.[a] But since Dönitz himself only saw a few dolmens which were furthermore empty, little is added to the sum of knowledge by him, especially in comparison with the highly interesting investigations of Gowland, who published the results of his work begun more than thirty years ago in the London Archeologia for 1897. Gowland himself has examined more than 400 of the 1,200 known dolmens, many of which were untouched, and has gathered a valuable collection of objects out of them, now exhibited in the British Museum.

The dolmens in Japan are all megalithic structures and were covered with tumuli, often of large dimensions. If many of them stand

[a] Zeitschrift für Ethnologie, Berlin.

uncovered now, it is because the tumulus has been removed by climatic influences or by the hand of man.

The simple stone chambers, or stone cists—that is, three perpendicular slabs of stone covered with a very large cap stone—are not found in Japan. This is the more remarkable from the fact that in Korea, mostly in the northern part, I have seen a great number of these, while megalithic dolmens appear to be lacking there.

The stones of the Japanese dolmens, particularly the roof stones, are often very large, but regularly hewn stones are the exception. There are, according to Gowland, only four dolmens of the last sort, and they belong to a comparatively recent period. Generally they are put together without any mortar (which, however, was doubtlessly known then) and the interstices filled with small stones.

Occasionally true rock graves are found, graves of regular shape hewn out of the rock. Judging from the finds in them they belong to the dolmen age. They differ in their whole execution from the primitive caves mentioned before.

Gowland differentiates four forms of the dolmens: First, the simple covered passage (allée couverte); second, the covered passage broadening out on one side at the inner end into a chamber; third, the same form with a symmetrical widening out on both sides (this is the most usual form), and fourth, dolmens with two separated chambers one lying behind the other.

It is likely that the last form always represents a later stage of development; perhaps also the social position of the deceased influenced the form.

The chambers are rectangular in shape. The length varies from 1½ to 8 meters; the gallery leading in is often longer. The breadth of the chambers is generally less than 3 meters and the average height about 2 meters, although it may rise to 5 meters. Some of them are vaultlike. The tumulus over the grave is sometimes as large as 30 meters in length and 10 in height, but usually only half that size. The entrance is almost always from the south, though frequently a little toward the east or west. Deviations amounting to 40°, which are observed in the large Japanese dolmen as well as in the small dolmens of Korea, can perhaps be explained from the time of year of the burial. East and west are easier to determine than true south, on account of the rising and setting of the sun. In midsummer the sun rises toward the north, in winter toward the south. If the people founded their orientation on the rising of the sun, as they probably did, south would be too far to the east in summer and too far to the west in winter.

Whether the peculiar position of the dolmen entrances toward the south is to be attributed solely to the sun and its worship, or whether it is based on some other religious or astronomical idea, it is difficult

to determine. I may remark in this connection that in China from the earliest times, the Emperor, the representative of heaven on earth, bore the title "The south looking Emperor." The bodies were buried uncremated, but the bones at the time of the examination had usually disintegrated. Where the position of the body could be determined it was generally laid in the direction of the long axis of the structure, that is, north and south. The bodies lay on the floor, which was rarely paved with stones or covered with plaster, but at other times sarcophagi of stone, terra cotta and wood were used.

One dolmen usually served for only one or two persons. Interment of a larger number was very infrequent and probably indicated a family vault or the death of many from some special occurrence.

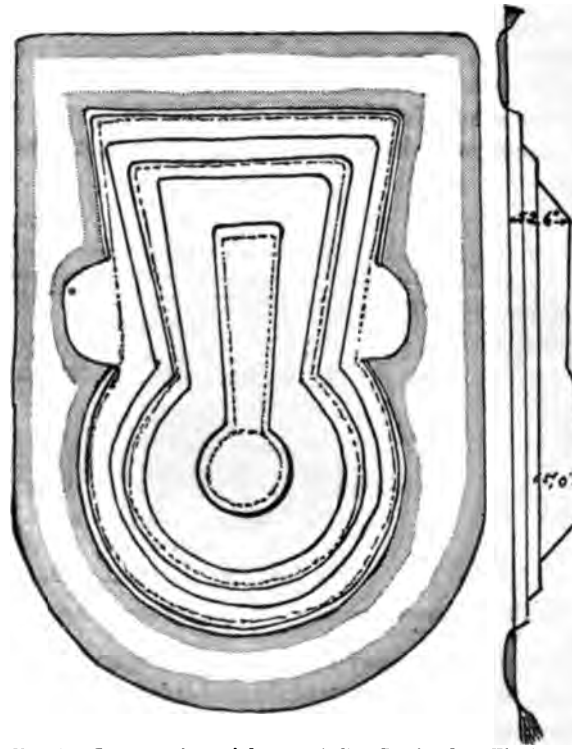


FIG. 6.—Japanese imperial grave (after Gowland). The length of the mound between water surfaces is 674 feet. The outlines of the mound recall the schematic outlines of a human figure. The dotted lines indicate rows of clay cylinders.

A particular form of grave is represented by the imperial graves (Jap. "Misasagi") of the dolmen period. They would be more appropriately termed princely graves, since they do not occur only in central Japan, where the Emperor always lived, but also in all the districts where dolmens abound, and which must be considered as the seats of great feudal princes. These graves are often only a kind of unusually large dolmen mounds, yet they are prominent not only by their often enormous dimensions, but they have other peculiarities. In contrast to the position of the dolmens on hills, these graves lie principally on plains. They are double mounds of a characteristic form (as the accompanying figure by Gowland shows), consisting of a trapezoidal mound flat on top and often terraced, joined to a higher circular one likewise flat on top.

Around the whole structure runs a large ditch or moat. The orientation of the long dimension is east and west. The entrance to the dolmen is in the south side about a third or half way up the circular mound. It contains one and often two stone or terra cotta sarcophagi. At other times the sarcophagi are buried in the mound without any real dolmen structure. The whole mound is surrounded at different levels by several rows of short, broad, hollow tubes of terra-cotta placed close together. The total number of these often runs up into the thousands. The terra cotta figures, called Tsutshinigyo (earth figures), are also found here, but only a few are preserved, since most of them soon crumble away in the open air.

An idea of the enormous labor which the erection of such grave mounds entailed may be obtained from the fact that one of these misasagi with its moat covers not less than 200 acres.

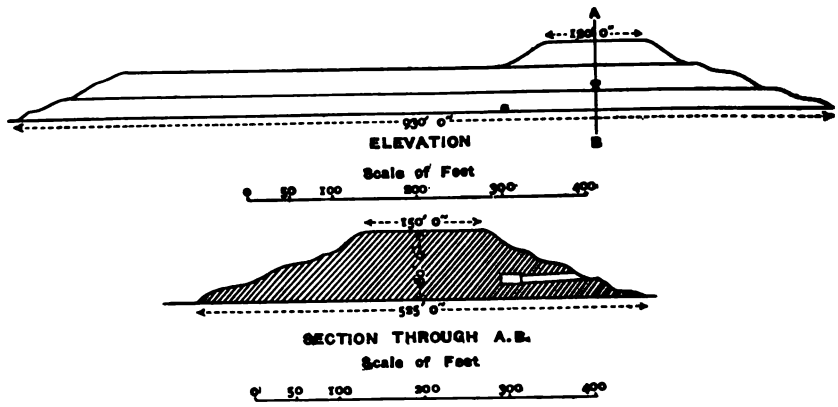


FIG. 7.—Japanese imperial grave in longitudinal and cross section. After Gowland.

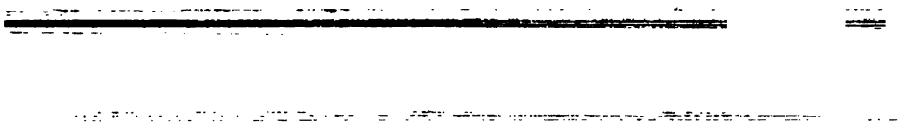
During the many centuries of Shogun rule, when the Emperor was a purely nominal potentate and lived almost a prisoner in his capital, these graves were so completely neglected that farmers laid out fields on some of them. Gowland found the largest grave mound he examined entirely given up to agriculture.

In 1868, however, the Emperor was fully reinstated in his rights and power, and since then all the imperial mounds have been rigorously protected. They are fenced in and Shinto temples have been erected at their foot. They are particularly numerous in the provinces of Yamato and Kawachi, and they have a very imposing and stately appearance as they rise from the plain. Each one is attributed to a special Emperor, but it is doubtful in some cases whether just that Emperor whose name the mausoleum bears lies there.

The objects found in the dolmen or rock graves are very numerous and often valuable from an artistic point of view.

JAPANESE SWORDS AND SWORD FITTINGS FROM GRAVES OF THE IRON AGE (DOLMEN PERIOD). BAELZ COLLECTION.

OBJECTS FROM JAPANESE GRAVES OF THE IRON AGE. BAELZ COLLECTION, ONE-THIRD NATURAL SIZE.



Of the weapons the most characteristic are the iron swords, which differ in form as much from the swords of the bronze age as from those of the later Japanese, which, as is well known, curve backward toward the point. The iron swords are perfectly straight, with a hilt long enough for both hands. The length of the cutting edge is generally from 80 to 100 cm., and the grip from 15 to 20 cm. The swords are incased in a wooden sheath. This is often covered by a copper sheath, on which in exceptional cases a gold sheath is hammered, with designs of dragons and other things.

These swords were not thrust into the girdle like the later Japanese swords, but hung at the girdle or belt of the wearer by a loop fastened to two eyelets on the sheath. Iron lances or spears appear to have been little used. Arrow points of iron and pieces of ornamental gilded bronze bits and horse trappings have been found. The Japanese of that time must have been keen horsemen, for such articles are often quite numerous in the more elaborate graves and are of varied and beautiful execution.

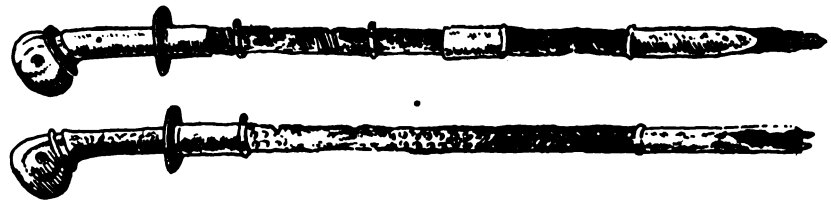


FIG. 8.—Swords ornamented with gold from a Japanese prince's grave. Museum in Tokyo.

Pieces of armor are rare, probably because the iron has been destroyed by rust. The Tokyo Museum, however, possesses some large and well-preserved specimens of iron breastplates and several helmets, one of them finely gilded. Out of the same grave with some of these objects was obtained a pair of perfectly preserved gold-plated copper shoes.

Although iron swords are much more common than bronze swords, it is doubtful in their case, too, whether they were made from native material. No mines nor iron works have been found, and even to-day Japan is a country poor in iron.

It is a remarkable fact that among the gifts of a King of Kudara (in Korea) in the third century A. D. fifty bars of iron are explicitly mentioned. A great many swords could be made from these.

Whatever bronze objects are found in the dolmen graves are in the form of ornaments. Bronze mirrors plainly coming from China (some of them being dated from the Han dynasty, 200 B. C. to 200 A. D.), little bronze bells for horses, horse bits and trappings, and bronze arrow points are among the most numerous. Besides these

there are gold-plated rings of iron or copper made without soldering of the same form and technique as those in the more elaborate graves of the bronze and iron age in Europe. Some small rings of solid gold or silver have also been found. Among the other ornaments may be mentioned little thin plates of gold and silver used as trimmings for clothes, glass and stone beads, and bugles. Gowland found no less than 1,018 specimens of these last ornaments in one dolmen grave, together with the comma-shaped magatama already mentioned. The last are not so numerous, however. Steatite, jasper, agate, rock crystal, and occasionally the foreign stones, chrysopras and nephrite, are used for this jewelry. The prevailing colors of the jewelry are blue for the beads and a dull green for the stones. In many graves are found small models in steatite of wooden shoes, combs, spindles, knives, daggers, arrow points, and some radially striped disk-shaped objects, whose significance is not known. They are, from their shape, called wagon-wheel stones by Japanese archeologists.

FIG. 9.—Clay vase with perforated base.

The pottery of the dolmens has been described in detail by Dönitz, and the principal forms are figured in his paper already quoted. He rejects the idea prevalent amongst the Japanese experts, of Korean origin or influence in regard to this pottery, as in his opinion the ancient Koreans themselves were unskilled potters, and as the Korean pottery used at the ceremonial Japanese tea ceremonies (cha no yu) was shaped by hand and was of a rough type, while the gray dolmen ware, although mostly unglazed, was always made on the wheel and is of a much higher artistic standing. The cha no yu ware, however, is of a much later date and only part of it comes from Korea, while the clay vessels found in the old Korean graves are unmistakably identical with the Japanese dolmen pottery.

In any case the fact remains that even before Christ artistic and well-formed vessels existed, which were shaped upon the wheel, and yet centuries later potters were brought over from Korea. In Japan itself the best potters must have lived, not in the imperial province of Yamato, but in the distant province of Idzumo, the seat of the most ancient culture, whither the Government sent again and again for potters when they were needed quickly.

In connection with the pretty conical stands or bases of some of the vases with triangular and rectangular holes, I may remark that I have seen in the museum at Cairo very ancient Egyptian clay vases with the same striking ornamentation. Dönitz thinks that the holes were put in to facilitate the baking. Gowland considers them entirely

ornamental. Perhaps a fire was made in the cavity to warm the liquid in the bowl or vase on the top.

There is a special sort of pottery which Dönitz does not mention, viz, the clay cylinders and figures which, unlike the gray vessels

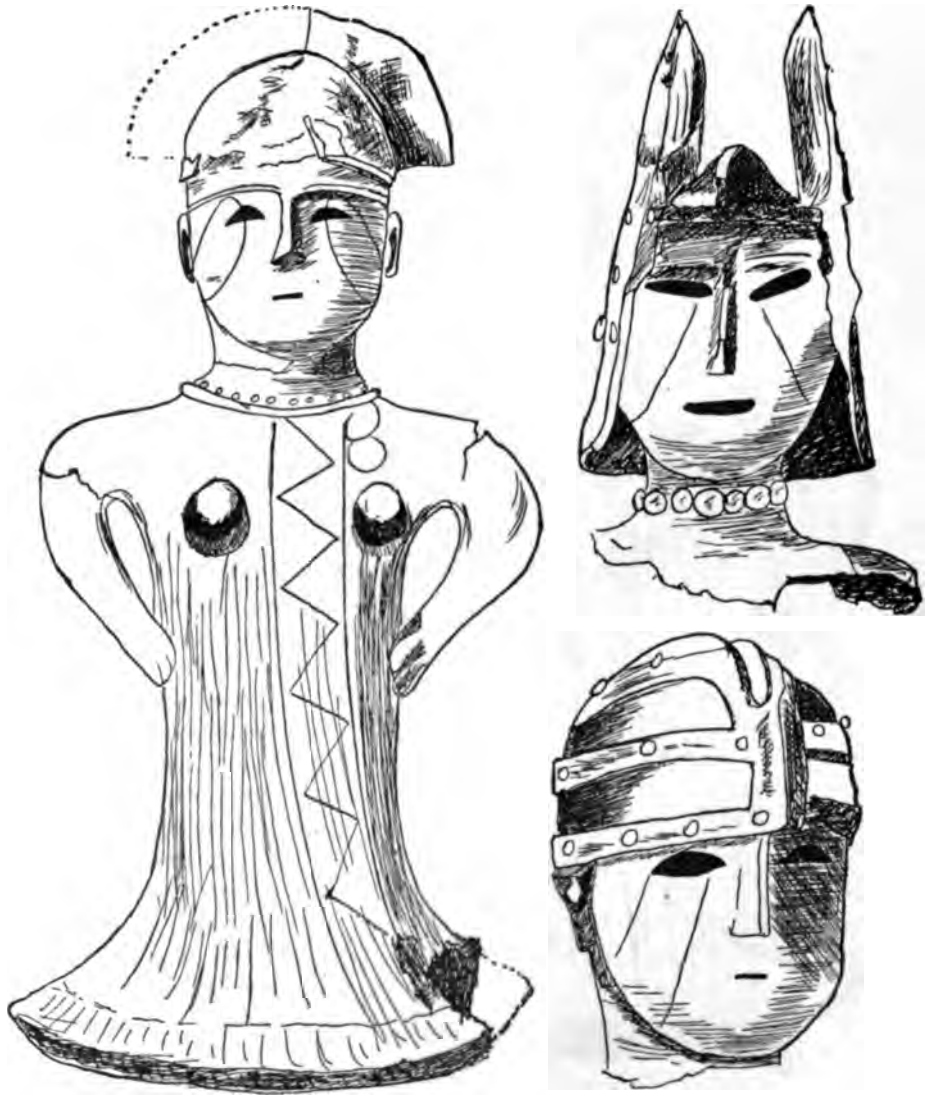


FIG. 10.—Terra cotta figures from princely graves of the iron age. The cheeks are painted red. After Tsuboi: Kokogaku (archeology).

occurring in the inside of the dolmen, are found on the outside of the imperial double grave mounds. They are made of a poorly baked red terra cotta, and for this reason are much inclined to disintegrate. The cylinders are about 40 cm. high and 30 to 35 cm. in

diameter, and stand by the hundreds or thousands in rows one above the other on the imperial graves. Their purpose is not known. It can, as Gowland says, hardly be to protect the mound from erosion by the weather, on account of their position, and it is also improbable that they were set up or laid there as a substitute for living servants buried with the illustrious dead. On the other hand, we may assume that the less frequent so-called Tsutshi-nigyo (that is, earth figures of men) found with the cylinders served that purpose. As in almost all half barbaric ancient countries, servants and slaves or war captives were killed at the tomb of a prince in Japan in order to serve him in the next world. In Japan this human sacrifice took the terrible form of burying the victim in the earth up to the breast, causing a lingering death from hunger and thirst or suffocation. An emperor is said to have been touched by the cries and groans of these unfortunates, which lasted several days and nights, and therefore, on the advice of a famous official, he issued an edict that in the future the human sacrifices should be stopped and the servants replaced by clay figures which were buried in the tumuli. Probably this was, as in so many other

FIG. 11.—Terra cotta figure with armor from the grave mound of a prince. After Tsuboi: Kokogaku.

cases in Japan, an imitation of a Chinese custom, since a substitution of stone figures for human sacrifices is mentioned there much earlier. These "Haniwa nigyo" or Tsutshi-nigyo, sometimes 60 cm. in height, are of value because they show the dress and armor and the ornaments of that period. They are also interesting in that they have the features which distinguish in Japan the refined north Mongolian type, of graceful, slender build, aquiline nose, and narrow slanting eyes, in strong contrast to the stone-age figures previously mentioned.

The horses formerly sacrificed at the tombs were also replaced by clay horses.

The distribution of the dolmens is interesting and at the same time gives an idea of the political and social state of affairs at that time. A glance at the map shows that geographically Japan is divided into two almost equal parts, a western half (somewhat south, to be sure), which includes a part of the main island and the great islands Kiuschiu and Skikoku, and another half running almost north and south, which is made up of the larger part of the main island and of Jezo. The two parts are joined almost at right angles by a broad isthmus at 136–137° longitude east of Greenwich and 34–35° northern latitude.

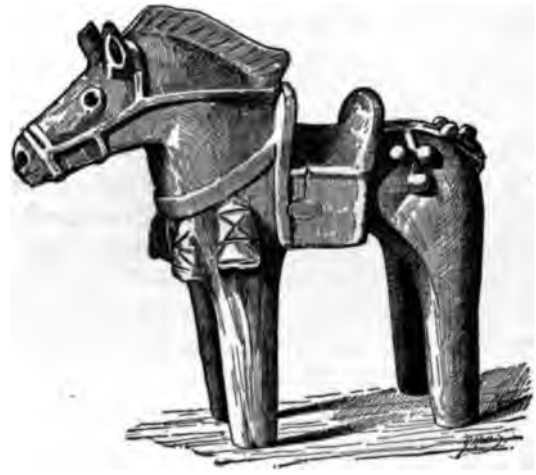


FIG. 12.—Clay horse from the grave mound of a prince of the iron-age Dolmen period.

This isthmus forms an important ethnical and civilizational boundary. The bronze culture is absolutely and the iron culture nearly confined to the country west of the isthmus. Northward of it is the main region of neolithic culture; only here are found the well-finished stone weapons and neolithic human clay figures in any quantity. In this large northern territory we find, however, one well-circumscribed oasis of iron-age culture with dolmens—the fertile plain around Tokio with the surrounding mountainous country.

Besides this isolated group in the north, we can distinguish five other centers for the dolmens, two of which lie in the great southern island of Kiushiu. The smaller one is near the Pacific, in the province of Hiuga, where the grandfather of the first Emperor is supposed to have come down from heaven and whence he is said to have started on his victorious march. This took him first to the north of the

Kiushiu. Here we find the second large dolmen region, includin the island of Tsushima and the provinces lying opposite the souther point of Korea, a region where bronze weapons are especially fr quent. This region was afterwards for a thousand years the seat c powerful vassals, who were often enough arrayed against the imperi court. From here, according to the Japanese annals, the first Emperc continued his journey across the bay of Shimonoseki to the mai island and marched along the shores of the inland sea. On this roa we encounter a third dolmen center in the province of Bizen. Th conquest at last reached its goal in the central provinces, the Gokina which were from then the seat of the imperial rule for more than tw thousand years. It is no wonder then that we find here the fourt and largest of the dolmen centers.

The fifth lies along the northwest coast of the principal island i and around the province of Idzumo, where, as mentioned above, th conquerors already found a civilized people. The sixth is that i and around the Tokyo plain.

Thus the legendary stories of ancient Japanese history are co roborated by the archeological finds. From these we learn that th invaders, a people in the iron-age culture, took possession of th fertile coast stretches in the southwest and spread out to the east ar north along the ocean. In Yamato and Idzumo they encounter organized communities of a cultivated and propably related rac these they subdued only after a fierce struggle. The regions where w find the Dolmen centers were ruled by feudal princes who for a lon time recognized the Emperor only as primus inter pares, since the were buried in a similar manner as the Emperor himself. The power was gradually absorbed by the emperors in Yamato, and a last these were able to proclaim themselves "sole rulers by the gra of the gods."

The period of the imperial mounds as well as of the commo dolmen mounds which are found in groups of 10 to 200 at the fo or on the slope of hills, probably began at least in the fourth centur B. C., perhaps a good deal earlier. Its end is fixed about the yea 70 A. [illegible] at that time an imperial edict was issued forbiddin this form of [illegible]. Cremation was then inaugurated under th influence of [illegible].

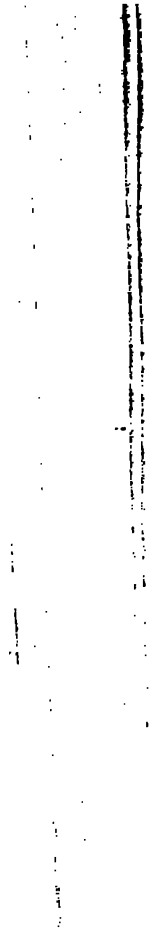
It is [illegible] the Japanese dolmens that (1 they are [illegible] age, but belong ex clusively to the [illegible] age [illegible] they are always of a megalithi nature, [illegible] having been foun so far in Japan [illegible] Korea; and tha [illegible] the country [illegible] isolated from al [illegible] It is necessary to go as far as th [illegible] anything lik

them. But their most similar counterparts existed in prehistoric Northern Europe.

In summing up the whole subject briefly we may say: The oldest inhabitants of Japan known to us, the Ainos, lived in the stone age and have left their traces in the shell heaps and many other places. Formerly they inhabited the whole island, but were gradually pressed towards the north, where the stone age prevailed even within the last thousand years, and where the products of that age reached the highest state of development. The present Ainos make pottery no longer; they have for a long time obtained their pottery and other vessels from the Japanese, when they could not use their own wood utensils.

In the second place, there lived in the southwestern part a people of the bronze age who did not reach the isthmus and the Biwa Lake towards the north. These either drove out or subjugated the aborigines of this region.

Finally there appeared in the southwest a conquering people of an iron-age culture that took possession of the territory of the bronze people and gradually extended their dominion over the whole island empire. In the seventh century A. D. they had only penetrated as far as the region somewhat north of Tokyo, near Sendaig. In central Japan, in Yamato and Idzumo, they had encountered and subdued organized tribes which were not in the bronze age, for there are no bronze weapons found in Yamato. Whether these tribes still used stone weapons or whether, as is far more probable, they already had iron is an open question.



THE ORIGIN OF EGYPTIAN CIVILIZATION.[a]

By EDOUARD NAVILLE, D. C. L., LL. D., etc.

Who were the Egyptians? Were they a native race, born in the country which they inhabited, or did they come from abroad as immigrants? Were they a mixed population, and if so, can we distinguish the various elements which formed the Egyptian nation? These questions have lately occupied most intensely the attention of Egyptologists. The excavations made during the last twenty years enable us to give an answer very different from the point of view advocated by such masters as Lepsius or E. de Rougé.[b]

For these two pioneers in the field of Egyptian learning the Asiatic origin of the Egyptians seemed a certainty, especially for Lepsius, who had been very much struck by the fact that the oldest monuments known in his time were the pyramids and the tombs around them, while in Ethiopia, as far as the province of Fazoql, he found nothing but very late monuments. The conclusion he drew from what he saw was that the Egyptians had come through the Isthmus of Suez, and that after having settled first at Memphis they had extended in the valley of the Nile, the civilization going up the river towards the south.

This idea seemed justified at a time when nothing was known of the beginning of civilization, which appeared from the first as complete with all its special characters. As no trace had yet been discovered of its first steps, of a lower and primitive stage out of which the Egyptian culture might have emerged, it was natural to suppose that we had before us an importation from abroad, and that, if not the whole, at least the principal features of the civilization were a product of Asia, whence they had been brought by the first settlers in the valley of the Nile.

One of the first to dispute the Asiatic origin of the Egyptians was M. Maspero, who in his History of Egypt (1895) states that "the

[a] Reprinted from the Journal of the Royal Anthropological Institute, Vol. XXXVII, 1907, by permission of the council.

[b] E. de Rougé's idea has been expounded by his son, J. de Rougé (Origine de la Race Egyptienne, Paris, 1895), "The starting point of the Egyptian peoples is to be looked for in Asia, where they lived in the neighborhood of the ancestors of the Chaldeans."

hypothesis of an Asiatic origin, however attractive it may seem, is somewhat difficult to maintain. The bulk of the Egyptian population presents the characteristics of those white races which have been found established from all antiquity, on the Mediterranean slope of the Libyan continent."[a]

Since M. Maspero wrote these lines, the excavations of MM. Petrie, Morgan, Amélineau, followed by several other explorers, have revealed to us the primitive state of the Egyptians—a degree of culture which had not gone beyond the stone age. The tombs discovered in various places have preserved not only the bodies of their primitive inhabitants, but also their implements, their tools, what I consider to be their idols, and pottery, the painted decoration of which shows their mode of life and their occupations.

These tombs caused great astonishment to the explorers who first opened them. The idea of an Egyptian burial was, till then, so intimately connected with mummification that it seemed strange to unearth small tombs of oval or rectangular form, in which the body lies without any trace of mummification. The skeleton is folded, the knees being against the chest, and the hands holding the knees or being at the height of the mouth. This has been called the embryonic position. It is not the only form of burial. Sometimes the body has been broken in pieces immediately after death; in other cases there is what is called a secondary burial. After the flesh had been destroyed, the bones have been gathered; occasionally an attempt has been made to give them the embryonic posture, or they have been jumbled together in the tomb; bones belonging to various bodies have been mixed, so that Mr. Petrie believed at first that those burials showed us the remains of feasts of cannibals. With the body pottery of different colors is found in the tombs, and also vases of hard stones, remarkably well made and finished, a few rude human figures, some of them characterized by the steatopyga which exists in other countries, and with distinct traces of tattooing, tools of ivory, flint instruments, of exquisite workmanship, and a great number of slate palettes. Sometimes the latter have the forms of animals, chiefly birds and fishes; others are mere lozenges. The purpose of these slates has not yet been clearly recognized. I am inclined to think that they are the images of food offerings, when they are in the hand of the deceased, who holds them up to his mouth, or they may be amulets or images of divinities.

That is a short description of what are called the prehistoric or predynastic tombs of the old Egyptians.[b] They were first discovered

[a] Dawn of Civilization, p. 45.

[b] Capart, "Les rites funéraires des Egyptiens préhistoriques," Annales de la Société Scientifique de Bruxelles, f. XXIV.

in middle Egypt; but, lately, so-called prehistoric cemeteries have been found nearly everywhere above the Delta, so that we have here a positive proof of the existence of a people which had not yet adopted Egyptian customs, but which occupied the whole of the valley. Therefore I can not consider the name "prehistoric" as being correct. No doubt the state of civilization revealed by these tombs is that which preceded Menes, the first historical king, but I can not admit that it should have ceased when the foreign invaders conquered the native race and settled in the valley. Certainly a vase in red pottery, with black rim, of the kind which is most commonly found in those tombs, may be prehistoric, but we have also definite proofs of that style of pottery having lasted at least till the twelfth dynasty in historic times. Evidently the native stock was very numerous; it was the bulk of the population, and its customs changed only by degrees. Let us consider what takes place at the present day. In the cities like Cairo or Alexandria we find all the refinements of civilization. At a few hours' distance, if we enter the tent of a Bedouin of the Delta, except for an old matchlock, what we shall see is much more similar to a prehistoric dwelling than to a product of the twentieth century.

Therefore I entirely disagree with the chronological classification which has been attempted of the so-called prehistoric pottery. I believe the true classification should be geographical. We have to notice the peculiar taste and style of each locality. Egypt is a very conservative country; besides, the fact of its not being concentrated around a city, but being a line which extends along the river, makes it much more difficult for an influence originating from the capital to be felt at the end of the country. Even at the present day tastes and fashions differ in the various localities. The pottery, for instance, is not the same at Sioot as it is at Keneh of Edfoo. It seems evident that it was the same in antiquity; besides, there might be differences in the degree of development. One locality, under favorable circumstances, may have made a certain progress, while another, more remote, without intercourse with its neighbors, may have preserved longer the rude and coarse style of old times. That does not mean that the rude and the more perfect vase could not be contemporaneous.

I should therefore propose that this name "prehistoric" should be dropped, and should be replaced by that of native, or rather African, civilization, for this is the result of the latest excavations. As far back as we can go we find in Egypt a native race, with customs and culture distinct from that of the later Egyptians, a culture which we must call indigenous, since we have no clue whatever to indicate that it came from abroad. This race does not seem to have progressed

further from the stone age, but to have attained a remarkable skill in working hard stones, ivory, and wood, not to speak of flint implements, of which they have left us magnificent specimens. This culture lasted late in historical times, and may have ceased at very different epochs in the various places where it existed.

I call this culture African. One of the distinct African features is the mode of burial which I mentioned before, the so-called embryonic posture. Herodotus, speaking of the African nation called the Nasamonians, says that "they bury their dead sitting, and are right careful, when the sick man is at the point of giving up the ghost, to make him sit and not let him die lying down."

Now, when Herodotus speaks of a man sitting, we must not fancy him resting on a chair. Seats do not belong to the furniture of a desert dwelling. He sits on his heels, and, in that posture, his chest leans against the knees, and his hands are at the height of his mouth. Hundreds of old Egyptian statues represent men in that position. Supposing that a man has died sitting and has fallen on his side; he has exactly the so-called embryonic position, which finds its explanation in that African custom. If afterwards vases with food and drink and some of his tools are put around him in his grave, his tomb will be the abridged image of the hut in which he sat in his lifetime; it will be his "eternal house," as the Memphite Egyptians called the tomb.

As for secondary burials, I believe the explanation is to be found in a custom still prevailing among some South American Indians, and of which, I am told, some examples have been found in old burials in Switzerland.[a] If a man dies at a great distance from the cemetery which is to be his grave, he is interred provisionally; sometime afterwards his bones are gathered and carried in a skin bag to the place where he is to be finally buried. This would explain the disorder which is sometimes noticeable in the bones of a tomb, and the fact that the bones of several skeletons have been mixed together. These skeletons have been brought from another place, after the flesh has been destroyed, and carelessly put into their grave.

These tombs give us interesting information as to the mode of life of the primitive Egyptian. We gather it chiefly from yellow vases, hand-made, and decorated with subjects in red painting. These drawings, being very rude, have received different interpretations. It seems to me evident that what they usually show us are not boats, but representations of dwellings. These dwellings were huts, placed on mounds, and probably made of wickerwork. They were surrounded by inclosures made of poles, something like what is called now a "zeriba," sheltering the inhabitants against wild beasts. There are

[a] I am indebted for that information to the kindness of my countryman, Mr. A. de Molin.

generally two huts with a kind of slope between them, which is the entrance. At the side of one is a standard pole, bearing either the symbol or the god of the village.

In these inclosures we see men whose life is that of hunters. They are armed with bows and spears; the animals are those of the desert —large birds, chiefly ostriches, gazelles, and antelopes, of which the rich Memphite Egyptians liked to have large flocks. Trees appear here and there, but the inhabitants of these villages do not seem to have practiced agriculture; we do not see cattle, neither oxen nor sheep nor asses, none of the domestic animals. Sometimes men are shown struggling against wild beasts, and women holding their hands over their heads, as if they were carrying a jar or a basket. Boats with sails will occasionally appear, therefore they knew how to navigate. The great number of slates in form of fishes are certainly a proof that they practiced fishing as well as hunting.

These people, who in some respects seem to have reached only a very rudimentary degree of civilization, knew how to make fine vases of very hard stone. Their flint instruments are among the finest known, but their sculpture is rude, not in animals, but in the representation of the human figure. The characteristic feature of this race is that they were hunters and not agriculturists.

As to their physical type; the views between the numerous experts who have studied Egyptian skulls are decidedly conflicting. However, they are unanimous on one point. They all agree that the prehistoric Egyptians were not negroes, that they had long hair, generally black, but sometimes fair, and that prognathism hardly appeared.

Some of the authors admit a negroid influence, and have come to the conclusion that there were two races, a negroid and a nonnegroid. This view is strongly attacked by others. If we look at the painting of a prehistoric grave found at Hieraconpolis, we find the men of a brown or reddish color, very like that of the Egyptians of later times.

As to the connection of the prehistoric Egyptians with the other races of North Africa, especially the Libyans and the Berbers, unquestionable evidence has been sought in craniology, or anthropometry. I can not help quoting the two following statements which are given as equally decisive, and which are derived from the same kind of arguments. Let us first hear Doctor MacIver: "What has anthropometry to say on the question whether the prehistoric Egyptians were or were not Libyans? The answer is most definite and explicit. The prehistoric Egyptians were a mixed race, the component elements of which it is difficult to analyze with exactness, but this mixed race as a whole was not Berber. * * *" And further, "it is impossible any longer to maintain the view that the prehistoric

Egyptians were Libyans."[a] If we turn to Professor Sergi, professor of anthropology at Rome, we find that he finishes his chapter on the physical character of the Libyans by the following words:[b] "The Egyptians were a racial branch from the same stock which gave origin to the Libyans specially so called, one of the four peoples of the Mediterranean." It is well known that Professor Sergi's statements rest mainly on the study of skulls considered in a point of view different from that of other anthropologists.

These two quite contradictory statements are the best proof that we can trust craniology in the main lines, in its broad distinctions, while it is no safe guide in the minor differences which constitute the ethnological characters. Virchow himself, the illustrious anthropologist, has declared that from the sight of a skull it is impossible to trace with certainty the ethnic position which it occupies.

Thus we find at the origin of the Egyptian civilization a people with the Caucasian type, with long hair, occupying the valley of the Nile, as far as Assuân and farther south. Even now various authors suppose that the valley was peopled from Asia, and that these prehistoric inhabitants came from the east. We see absolutely no reason to dispute their native character. We can not touch here the vexed question of how the different nations were born, and how, leaving their cradle, they dispersed in the various parts of the world. We must take them when they first appear as nations. At the first sight which we have of the Egyptians, they show themselves to us as Africans, having some connection with the neighboring natives of the west, Libyans and Berbers, as they are called now, Tehennu and Tamahu as they are styled in the Egyptian inscriptions.

Certainly their civilization, such as it appears in the prehistoric tombs, is no foreign import. It is so completely determined by the nature of the soil and by the animals and plants which occupied the land that we are compelled to affirm that it is of African growth.

It seems nearly certain that in that remote epoch the white races of the north extended farther south than they did later, and that they were driven northwards by the negroes. If we consult an inscription of the fifth dynasty of the old empire, found in the tomb of an officer called Herkhûf at Assuân, we read that he went to a country called Amam, which could not be farther north than Khartûm or the Soudan. The people of Amam wished to drive the Tamahu toward "the western corner of the sky." He himself went through Amam, reached the Tamahu, and pacified them, so that at that time the Tamahu must have occupied countries now called Kordofân or Darfur, or perhaps Borku. Later on, in the struggles which the Libyans waged against the Egyptians, we find them inhabiting

[a] D. Randall-MacIver and A. Wilkin, Libyan Notes, pp. 103, 107.

[b] G. Sergi, The Mediterranean Race, p. 83.

the desert on the west of the Delta. Evidently the negro races must have invaded the territory which the Tamahu originally occupied, and compelled them to settle near the coast, where we find them under the Pharaohs of the twentieth dynasty.

With the Tamahu are often mentioned the Tehennu, a name which means "the yellow ones." I consider them as being one of the African nations of a color lighter than that of the Egyptians, a difference which is so easily noticeable in Cairo in going to the Tunis bazaar.

I believe the name of the prehistoric Egyptians has been preserved. They are called the *Anu*. The sign *An*, with which their name is written, means a pillar, a column of stone or wood, or, even as Brugsch translates, a heap of stones. According to Brugsch also, their name *Anu*, or, in the latter inscriptions *Anti*, means the Troglodytes or the Trogodytes, the inhabitants of caverns, and in Ptolemaic times this name applied to the Kushite nations occupying the land between the Nile and the Red Sea.

But we find them much earlier; they often occur at Anu Ta Khent, the Anu of Lower Nubia and of Khent Hunnefer, the southern part of Nubia. An inscription in the Temple of Deir el Bahari speaks of the Anu of Khent, Lower Nubia, of Khent Hunnefer, Upper Nubia, and of Setet, which, in the texts of the Pyramids is clearly the land of the goddesses Sati and Anqet, the land and islands of the cataracts.[a] The Anu are found much farther north. In the inscriptions of Sinai we see the King Khufu striking the Anu, the inhabitants of the mountains who are evidently the population he conquered when he invaded the peninsula.

An is the name of Heliopolis, one of the oldest cities in Egypt, and the religious capital of the country. The same name, with a feminine termination, is Anit, which means Tentrya (Dendereh), but also Latopolis (Esneh) and Hermonthis (Erment). The land of Egypt is often called the two lands of An, so that we can trace the name of An, not only among the neighboring nations of Egypt, but in the country itself, from an early antiquity. Evidently this name—the two lands of An—for Egypt, is a remainder of the old native stock before the conquest.

Anti, a word with an adjective form, means a bow. The sense of the word seems to be "that of the Anu, the weapon of the Anu." We can recognize the Anu in those archers who are represented several times on the slate palettes, which, although later than the conquest, are among the oldest monuments of Egypt. The Anu use arrows with triangular flint points. More often we see them as unarmed men with pointed beards, trodden down by the king, who has taken the form of the divine bull Bat, or torn to pieces by a li

[a] W. Max Müller, Asien und Europa, p. 20.

An ivory blade found by Mr. Petrie shows a bearded prisoner standing, over whom is written Setet, the land of the cataracts, which, as we have seen it, is one of the countries inhabited by the Anu.

Several Egyptologists have admitted that the Anu were foreign invaders who had been repelled by the Egyptians. On the contrary, I conclude, from what has been discovered lately, that they were the native stock occupying the valley of the Nile, and that they had been conquered by invaders, who very soon amalgamated so completely with their subjects that they formed one single people.

The aboriginal stock, as we saw, had carried the civilization to a certain point. But it is clear that before the historical times, at an epoch which we can not fix, a foreign element entered the valley of the Nile, subdued the Anu, taught them a culture which was unknown before, and created the Egyptian Empire.

With this invasion appears the hieroglyphical writing, which seems to have been unknown to the native stock. This writing has such an absolutely Egyptian character that it must have originated, or rather developed, in the country itself. We do not know any written monument which we may trace to the African dwellers of the country. On the slates and cylinders which are later than the conquest, and which are the oldest written remains which have been preserved, we find signs with an archaic character, but which lasted through the whole time when hieroglyphical writing existed.

Let us first consider how the conquerors designated their kings. It was done in a peculiar manner, in a shape which is always the same. At the top of the group is a bird, usually said to be a hawk, but which M. Loret has recognized to be the peregrine falcon. The bird stands on an oblong rectangle, often called a banner, at the lower part of which is a drawing showing the façade of a funeral chapel, the doorway giving access to the *ka*, viz, the double of the deceased. Above the drawing and below the bird are a few signs which, whenever we understand them, give us an epithet, a qualification of the king. Therefore, it is not his name, it is his first title, the first part of the complicated protocol, which will develop into a sentence, and which forms the royal name of the Pharaohs.

Thus, every king is a hawk, or, as we said, a falcon, the bird which is the symbol of the god Horus, and by which his name was written throughout the Egyptian history from its earliest beginnings to the time of the Romans. The king is the god Horus. This name leads us to Arabia, where the falcon is called *horr*.[a] This is the country where we have to look for the starting point of the race which conquered Egypt. If we consult the Egyptian inscriptions, we shall find that, on both sides of the Red Sea, in Arabia as well as in Africa, there

[a] Loret, Horus-le-Faucon, p. 20.

was a region which has had various names. One of them is *Kush*, wrongly translated Ethiopia; another is *Punt*, very frequent in Egyptian texts, where it is synonymous with *Tanuter*, the divine land. It seems that the region originally called by that name was southern Arabia, whence the populations emigrated, which settled on the African coast. We do not know exactly the appearance of the race in that remote time, but the sculptures of the Temple of Queen Hatshepsu at Deir-el-Bahari show us what was the appearance of the people at Punt. At that time the population of the country was mixed; it contained negroes of different kinds, brown and black, but the real Puntites, or Punites, as I think their name must be read, are very like the Egyptians. They belong also to the Caucasian type, with long hair and pointed beards. Their color is a little more purple-hued than than of the Egyptians.

Here a very important question arises. Did the Punites, the inhabitants of southern Arabia, belong to the Semitic stock? Looking at the information which we have derived lately from Arabia and from Babylonia, I have come to the conclusion that they were not Semites. They were Hamites, like the Egyptians themselves and some of the north African populations, and like some of the inhabitants of Chaldæa, whose origin is also attributed by a few scholars to Arabia, so that they should have the same starting point. No doubt I shall hear the objection that Egyptian is a Semitic language. My answer is that the better we know the Egyptian language the more fully we grasp the conceptions of the Egyptian mind, the more it seems evident that Egyptian is an ante-Semitic or pre-Semitic language. In certain points it has kept the character of infancy. Semitic languages are in a more advanced linguistic stage; they have outgrown by far the degree of development which Egyptian has reached. To my mind we have to reverse the method which is generally followed. We are not to look for the origin of Egyptian in the Semitic languages, but, on the contrary, to see that what the Semitic languages have borrowed from the old Egyptian speech and writing.

The Arabian origin of the Egyptians is mentioned by the Numidian King and writer, Juba,[a] quoted by Pliny. After having given the names of the various tribes of the Troglodytes, the inhabitants of the African coast, between the Nile and the Red Sea, the writer says: "As for the neighbors of the Nile from Syene to Meroe, they are not Ethiopian nations, but Arabs. Even the city of the Sun, not far distant from Memphis, is said to have been founded by the Arabs." Thus for Juba the Egyptians are Arabs. When he says that they are not Ethiopians, we must consider this word as meaning negroes.

[a] Muller, Fragm. Hist. Graec., III, p. 477.

The Arabian origin of the Egyptian population is adopted by several scholars, but opinions differ as to the way they followed in their invasion. I said before that the opinion of Lepsius, who supposed them to have come through the isthmus of Suez, is now abandoned. Professor Petrie thinks that they came through the harbor of Kosseir, and that, after having followed the valley of Hamamât, they reached the region where is now the city of Keneh, and where was the old Egyptian city of Coptos. But if we study the traditions of the Egyptians, which are to a certain degree confirmed by the Greek writers, we come to the conclusion that the conquerors must have crossed the Red Sea farther south than Kosseir, perhaps in the region where is now Massowah, and that they stopped some time in the valley of the Nile, in the Sudan, before they came down and settled below the cataracts.

This has been translated by Diodorus in this way: The Greek writer says, "That the Ethiopians assert that Egypt is one of their colonies; there are striking likenesses between the laws and the customs of both lands; the kings wear the same dress and the uræus adorns their diadem." In this case we must give the name of Ethiopians another sense than in the quotation from Juba. It does not mean negroes, but the African population called the Anu of Nubia.

If we consult Egyptian inscriptions, we find that, without any exception, the south always comes first. The north is never spoken of as an ancient resort from which the population should have issued. The south has always the preeminence over the north. The kings of the south are mentioned before those of the north; the usual name for king properly means "King of the South." In his orientation, when he fixes his cardinal points, the Egyptian turns toward the south, so that the west is with him the right side. That does not mean that he is marching toward the south. In the mythological inscriptions we read that Horus first resided in the south, and coming down the river, conquered the country as far as the sea. The Egyptian looks toward the direction whence his god originally came. This direction is at the same time that of the Nile, of another form of the god who gives him life, and allows him to exist. The mythological narrative of the conquest of Egypt by the god Horus is of the time of the Ptolemies. The enemies of the god take the forms of animals, and are led by Set. Horus conquers the land for his father, Harmachis, who is the king. "In the year 363," says the text, "His Majesty was in Nubia, and his numberless soldiers with him." Horus is the general who leads the soldiers, while his father remains in his boat. Battles are fought in various places along the river; all of the episodes of the struggle are recorded by the names given to localities, to temples or to religious objects such as sacred boats. The last encounter takes place on the northern boundary of

Egypt, on the Pelusiac branch of the Nile, at the fortress of Zar, now Kantarah. This narrative seems certainly a late remembrance of an establishment in the valley of the Nile of a warlike race coming from the south.

In the monuments of the first dynasties which have been discovered at Abydos and elsewhere there is a record of the conquest and of the subjection of the native stock. It is a festival called the festival of Striking the Anu.

The oldest representation of it is on the large slate found by Mr. Quibell at Hieraconpolis. The king, preceded by the queen and by four standard bearers, is shown entering a hall where his enemies are seen lying down with their heads cut off and put between their feet. The proofs that the enemies of the king are the Anu is the ivory blade, which we quoted before, on which a prisoner is seen coming from the country of the cataracts, which we know was inhabited by the Anu; also a tablet found by Mr. Petrie[a] on which we read that "the heads or the chiefs of the Anu are brought to the great hall."(?) And lastly, another tablet on which the signs are more doubtful, but which speaks perhaps of the defeat of the Nubians.[b]

On the other side of the slate palette we see the same king holding his enemy by a tuft of hair and striking him with his mace. This scene is also engraved on a small ivory tablet belonging to King Den, and on ivory cylinders, where the king striking his enemies is repeated many times. We have already mentioned the sculpture of King Khufu at Sinai, where he is seen striking in the same way the Anu of Sinai. It seems to have been the typical and conventional way of representing the victory of the invader over the native inhabitants, and it occurs several times in the old empire. Later on it changed. Instead of one single enemy we see a great number of various races. The king holds them bound together by their hair and fells them at a blow. This, in my opinion, does not record victories which the king himself has achieved; it is a conventional and symbolical way of indicating that he belongs to the predominant race, that he can trace his descent to the conquerors of the Anu. The cluster of enemies held together is only a modification of the original scene, which may be invested with a ceremony at the coronation.

The festival of the Striking of the Anu is mentioned in the Palermo stone, a document of the old empire, showing that the tradition persisted. Even as late as the eighteenth dynasty, this festival was celebrated by Thothmes III.[c]

The monuments of the first dynasties found at Abydos and Hieraconpolis give us an idea of the civilization of the foreign invaders.

[a] Royal Tombs, I, pp. 16, 20.
[b] Ibid., II, p. 32.
[c] Leps., Denkm., III, p. 55.

As soon as they appear we see domestic animals, the bull, the ass, the sheep, which are not found on the pictures of the prehistoric vases. The careful researches made by Doctor Lortet on the mummies of Egyptian bulls have led him to the conclusion that the long-horned bull, which is the oldest breed found on the monuments, is a native race and has not been imported from Asia. Doctor Lortet says the same of the ass and of the sheep. Thus the foreign invaders domesticated the animals which they found in the country. The fact of their having practiced domestication implies that in that people there was a propensity toward civilization and progress, which did not exist in the natives. Probably also they were agriculturists. When they settled below the cataracts they took with them the papyrus, which even now is found on the upper Nile, although it has disappeared entirely from Egypt. This plant was used for various purposes, and not only for making paper.

Looking at their civilization in general, we find that there is hardly an element of it which could not originate in Egypt. They must soon have perceived that dry Nile mud was a very good material for building, which did not require to be burnt. The art of building certainly began in Egypt with brick and wood. The first step afterwards was to replace the bricks by stone, of which there were various kinds particularly well suited for that purpose. It is natural that, having such fine material as the sandstone of Silsilis, the limestone from the quarries of Turâh and Thebes, the diorite and black granite from Hamamât, and especially the beautiful red granite from Assuân, the Egyptians should have become great builders. It is perhaps the only art in which they far excelled the neighboring nations, much more than in sculpture or in painting.

As we have said before, the writing also is of decidedly Egyptian origin. We can find in it no trace of a foreign element. Civilization seems to have grown entirely in the last settlement of the invaders. They adopted and developed the rudimentary culture of their subjects. They improved it so as to produce the admirable display of Egyptian art and industry which occurs under the fourth dynasty. If the followers of Horus had brought their animals from Arabia, one would expect to see among them the horse, which does not appear before the Hyksos invasion. If they had been already civilized before reaching Africa they would have left traces of their passage in the various places where they stopped. At present no vestiges of an early Egyptian civilization have been discovered in southern Arabia, or even on the upper Nile. However, there is one side of their culture which decidedly comes from abroad, the art of working metal. Except, perhaps, for a little gold in the country between the Nile and the Red Sea, no metal is found in Egypt, neither copper nor iron. The arrows of the Anu certainly

had flint points, and, although the Anu were very skilled in the way they made and used their flint instruments, they did not employ metal. If we consult the inscription of the conquest of Egypt by Horus, we see that his companions are often called *Mesennu*, blacksmiths, who knew also how to cut stone and wood, but whose chief art was that of working metal. Horus gives settlements to his companions in various parts of Egypt. I believe metallurgy must have originated from the necessity of having instruments for the culture of the soil. One can imagine the Horian invaders stopping in a land of remarkable fertility and feeling induced naturally to improve the means they had of deriving advantage from the admirable soil of the country which they had chosen for their abode. It seems to me that at the beginning metallurgy was the associate of agriculture; later on it was used only for the fabrication of weapons.

We said before that the Horians probably brought into Egypt from their original resort on the upper Nile that most useful plant, the papyrus. Another plant which is often mentioned in the inscriptions of the first dynasties is the vine. On the clay sealings of the big jars discovered at Abydos mention is often made of the vineyards from which the wine contained in the jars is derived. Did the vine come to Egypt from Asia? Here again we can trace an African origin for this plant. De Candolle, in his book on the cultivated plants, says that the vine grows spontaneously in southern Europe, in Algeria, and Morocco. The same botanist lays stress on the possible dissemination of the plant through natural causes, like the birds, the wind, and the currents. In the oldest lists of offerings several kinds of wine are quoted. When the lists become more detailed and complete the names of the localities from which they come are given. They are most of them places in the Delta.

In the new empire the good quality of the wine from the various oases is often praised. There it seems probable that the plant came from Africa; the oases always had more connection with Africa—with the west— than with the east. We hear of the Libyan wines brought by the Tamahu. They are known to Strabo as well as those from Mareotis. Thus, even for the vine, we are not obliged to admit an importation from Asia.

The Egyptian, and after them the Greek writers, tell us that the first historical king was Mena or Menes. Herodotus adds that in his time all Egypt except the Thebaid was a marsh. Mena is said to have founded Memphis and its Temple of Ptah, and also to have built a great dike in order to regulate the course of the Nile. According to Diodorus, Menes taught his people to fear the gods and to offer them sacrifices; also to make use of tables and beds and of fine garments. He introduced luxury among his subjects.

It is usual now to speak of pre-Menite kings. I believe this to be a mere hypothesis. The tradition of Menes having been the first king rests on Egyptian monuments, and is recorded by Greek authors. When a sovereign like Rameses II engraved on a temple a list of his predecessors I can not help thinking that he began with the first, and he would not have put aside the kings who were before Menes, especially when their graves or their funeral chapels were only a short distance from the temple where he engraved his list.

As for Menes, except for the scanty information which we get chiefly from the Greek authors, we are reduced to conjectures. Undoubtedly he belonged to the race of the conquerors, to the civilizers, but I should not think that he was the leader of the conquest. The tribe of Horus must have been settled in the country some centuries before him. They must have had time to develop the civilization which we find under the first dynasties. He probably was the first to unite the whole country under his rule, and thus he was the founder of the Egyptian kingdom.

One may fancy that the native stock, the Anu, consisted of various tribes, each having as its central point the village where, as we see on the potteries, the symbol or god of the tribe was put up on a pole as a standard. These symbols are the only religious element, the only trace of worship which we notice on the drawings of the potteries. The tribe of Horus did not eradicate the local cults. As time went on the standards became the great divinity of each nome or province. I believe this is the explanation of the great number of local gods which we find in Egypt. They were at first the tutelary divinity of a small clan of aborigines. The conquerors seem to have preserved the religious traditions of their subjects; for instance, one of the most ancient cities of Egypt, its religious capital, where was taught a cosmogonic doctrine, which was adopted more or less in the whole land, Heliopolis, is called An. It has the name of the Anu. These ancient natives appear in later times in religious ceremonies such as the Sed Festival celebrated by Osorkon II, of the twenty-second dynasty at Bubastis. There does not seem to have existed between conquerors and subjects an irreconcilable religious feud such as there was later between the Hyksos and the Egyptians. It would have prevented their mixing together and becoming one nation.

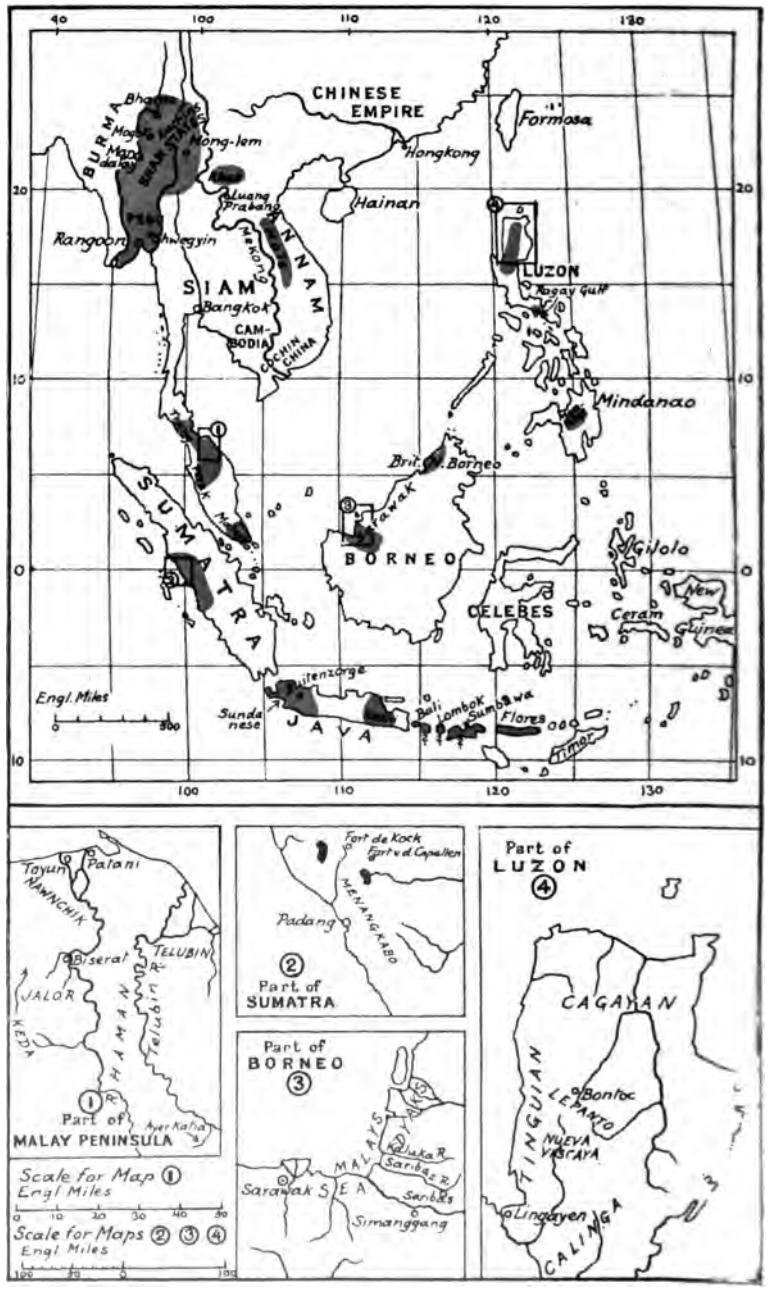
The relics of the first three dynasties show an extraordinary development of all ceremonies and customs concerning religion. Besides Horus, the falcon, which is the symbol of the king, the royal god, there are other divine animals, like the jackal, the god Apuatu, the god who shows the ways; and also a bull, or rather, judging from the nature of the animal, a buffalo. The hierarchy of priests is already fixed; court employments are mentioned, and festivals which will go through the whole of Egyptian history, like the Sed Festival,

which I think to be an indiction. The rites of the foundation of temples are very similar to what they will be in Roman times. Hieroglyphs are sculptured, very archaic in appearance; they are the first rudiments of the hieroglyphical alphabet, which is already fully developed in the fourth and fifth dynasties.

Very interesting religious objects are the slate palettes, having on one side near the middle a circular depression surrounded by a ring. These slates are often sculptured, and bear animals or war scenes, or representations of festivals, such as that of Striking the Anu. On such slates with a depression there are sculptures on both sides. Therefore I can not admit, with Professor Petrie, that these depressions were made for mixing green paint. If that was their purpose, there was no reason for their being so large as that found at Heiraconpolis, and for being adorned with such fine sculptures, not to speak of their being quite inappropriate for mixing colors. I believe this depression contained a religious emblem, a piece of wood or precious stone, which had the form either of a knob or of a bud. It corresponds exactly with the description which Quintus Curtius gives us of the appearance of the god in the oasis of Jupiter Ammon. The god had the form of an "umbilicus." This knob on the Hieraconpolis palette has a guard of two panthers or leopards; in other cases, of two dogs. This is not the only form of the god who had the name of *Bat*. He may be a bull with one or two heads, and also a tree. In that case the two leopards are replaced by two other spotted animals, giraffes, one standing on either side of the tree. We have here an example of tree worship, such as was practiced in Crete and in the Ægean islands.

In conclusion, such are the principal features of the civilization of the early Egyptian dynasties. It belongs to a nation formed by an indigenous stock, of African origin, among which settled conquerors coming from Arabia, from the same starting point as the Chaldeans. This explains a certain similarity between Egypt and Babylon. The foreign element was not Semitic. They belonged, like the natives, to the Hamitic stock; therefore they easily amalgamated with the aborigines, into whom they infused their more progressive and active spirit. The result was the Egyptians such as we know them under the first three dynasties, or, as we call that time, the Thinite period. At the end of it something took place which we can not yet explain—a sudden bound from the rude culture of the Thinites to the refinement in art and industry and to the literary growth which are exhibited by the fourth dynasty and afterwards. Has there been a new invasion, coming this time from Asia? It is possible; but there again we have no historical evidence of any kind, and we have to resort to conjecture.

The dawn of Egyptian civilization, which we have to place at a very early period, is certainly a distinct proof of the important part played by Africa in the history of human culture. Whether the whole region of the Mediterranean was first peopled by Hamites, as is now asserted by various authors, I do not feel competent to decide. But it seems to me unquestionable that the Hamitic civilization has been the first in date, and that it has largely influenced the islands and the neighboring nations. When we look at the startling results of the excavations in Crete, when we remember that this island is the natural bridge between Egypt and the Hellenic peninsula, we can not help concluding, with one of the excavators of the "house of Minos," Doctor MacKenzie, that the races who were the bearers of the Ægean civilization came from the south.



DISTRIBUTION OF THE ORIENTAL FIRE PISTON.

THE FIRE PISTON.[a]

By HENRY BALFOUR, M. A.,
Curator of the Pitt-Rivers Museum, Oxford.

The fire piston appears to have been but little known to ethnographers at the time when Dr. E. B. Tylor published his Researches into the Early History of Mankind,[b] which contains the classical and fascinating chapter upon fire making, one of the pioneering articles upon this interesting subject. Doctor Tylor refers (p. 246) very briefly to this instrument as follows: "There is a well-known scientific toy made to show that heat is generated by compression of air. It consists of a brass tube closed at one end, into which a packed piston is sharply forced down, thus igniting a piece of tinder within the tube. It is curious to find an apparatus on this principle (made in hard wood, ivory, etc.) used as a practical means of making fire in Birmah, and even among the Malays." If, taking this short sentence as my text, I make an attempt to bring together the available information regarding this peculiar fire-producing appliance, I trust that I may, however inadequately, be offering as my contribution to this volume a subject which at least has the sympathy of the honored and veteran anthropologist, to whom the book is dedicated.[c] Doctor Tylor's reference to the fire piston contains two statements, (1) that it is a well-known scientific toy, (2) that it is a useful appliance in certain eastern regions. I may conveniently divide my subject in a similar fashion and deal firstly with the "scientific toy" and its practical descendants as they exist or have existed in civilized Europe, and secondly with the "useful appliance" as it is found amid an environment of lower culture in the East. An interesting ethnological problem is involved, one whose solution is somewhat baffling.

[a] Reprinted, by permission of the author and the delegates of the Clarendon Press, Oxford, from Anthropological Essays presented to Edward Burnett Tylor in honor of his 75th birthday, Oct. 2, 1907.

[b] London, 1878.

[c] Edward Burnett Tylor.

THE FIRE PISTON IN EUROPE.

Appreciation by physicists of the scientific fact that heat and cold may be produced by the mechanical condensation and rarefaction of gases dates back to before the commencement of last century. A paper upon this subject was read by John Dalton in the year 1800,[a] giving the results of experiments in the compression and rarefaction of air, which were noted as producing increased and decreased temperatures. On December 29, 1802, M. Mollet, professor of physics in the Central School at Lyons, announced to the Institute of France that he had noticed that tinder could be ignited by placing a small piece in the narrow channel with which the lower end of a pump for condensing the air in an ordinary condensation pump is furnished. Two or three strokes of the piston were usually sufficient to cause a spark.[b] He also stated that he had observed a luminous appearance caused by the discharge from an air gun in the dark. On the strength of this announcement, J. C. Poggendorff[c] refers to Mollet as the discoverer of the Tachypyrion (instrument for producing fire by compression of air). On the other hand, we may gather from F. Rosenberger[d] that a workman in the small-arms factory at Etienne-en-Forez (near Lyons) was the actual discoverer of the fact that a great amount of heat was generated in charging an air gun with an ordinary compression pump, and that tinder could be ignited thereby. Mollet is here stated to have communicated this discovery by the workman, who must, if Rosenberger's account is the true one, be credited as being the original French observer of this phenomenon, Mollet having acted as the reporter of the discovery. The facts announced were not understood by the French scientists, who were inclined to discredit them, but very soon the experiment with the air-compression pump was repeated by others, and tinder (amadou) was easily ignited by this means. A letter was sent by M. A. Pictet, one of the editors of the Bibliothèque Britannique, to Mr. Tilloch in England, on January 1, 1803, announcing Mollet's communication to the Institute of France,[e] and the writer stated that he considered the phenomenon as never having been noticed before. But William Nicholson affirmed[f] that it (the flash from an air gun) had been

[a] Mem. Manchester Lit. and Phil. Soc., V. pt. II, p. 515, 1802.

[b] Journal de Physique, LVIII, 1804, p. 457; Nicholson's Journal of Nat. Philosophy, Chemistry, and the Arts, IV, 1803; Philosophical Magazine, XIV, p. 363.

[c] Biograph.-Literarisches Handwörterbuch, II, 1863, Leipzig.

[d] Geschichte d. Physik, 1887, III, p. 224.

[e] Philosophical Magazine, XIV, p. 363.

[f] Nicholson's Journal, l. c.; Marc Auguste Pictet, "Sur l'échauffement des projectiles par leur frottement contre l'air," Bibliothèque Britannique, XXIII, 1803, pp. 331–336.

known for some time in England, having been first mentioned nearly a year and a half previously by Mr. Fletcher at a meeting for philosophical experiments and conversations, which was then held weekly at Mr. Nicholson's house. He adds, "It is a curious phenomenon, and deserves investigation." No one at the time explained the cause of the phenomenon, which had been accidentally noticed and had not been arrived at by direct scientific experiment. Nicholson's statement is interesting, not only as assigning the first observation of this physical effect to an earlier date (somewhere about the middle of the year 1801), but also as ascribing to an Englishman its discovery.

In later days the experiment of igniting tinder in a compression pump became a common one in physical laboratories, and fire pistons were specially made for the purpose. These consist usually of cylinders of brass, closed at the lower end and very accurately bored or gauged. Into the bore fits a piston rod, carefully packed at the lower end, so as to occupy the bore as completely as possible. At the lower extremity of this piston rod is a cup-like depression, in which a piece of amadou can be placed. By driving the piston rod home very forcibly the column of air in the cylinder is violently compressed into a fraction of its normal length, the sudden condensation generating an amount of heat amply sufficient to ignite the tinder. The piston rod is at once withdrawn as quickly as possible and the tinder is found to be glowing, and a sulphured match may be lighted from it. In place of the brass cylinder and piston one of glass may be used, and the vapor of carbon bisulphide can be exploded by the compression, the flash being plainly visible through the glass.

Not only was this principle adapted for scientific illustration, but it was also applied to domestic use. Who was the first person to adapt the air-compression method for use in everyday life may never be known. We know, however, that its potentialities for utilitarian purposes were recognized not very long after the scientific interest had been roused. Among the specifications of English patents for the year 1807 there is one, dated February 5, No. 3007, recording an invention by Richard Lorentz of "an instrument for producing instantaneous fire." The figure of this instrument is reproduced here (fig. 1 on pl. II), and specification runs as follows:

The illustration shows the construction of my machine or instrument for producing instantaneous fire. *a* represents the cap or head of a staff or stick, having therein a cavity or space for containing the prepared fungus known by the name of German tinder, or for containing common tinder of rags, or any other very combustible substance. *c* is the outer end of the rod of a syringe, which works by a piston in the upper part of the staff, and by a stroke of about twelve inches forces the common air with great velocity and in an highly condensed state through a small aperture against the combustible matter included

in the head *a*, which is well screwed on against a shoulder or face armed with a collar of leathers. *b* is the hole for admitting common air when the piston is drawn quite back. The manner of working consists simply in pressing the end of the rod of the charged syringe strongly against the ground so as to drive the air suddenly on the tinder, and the cap *a* being without loss of time unscrewed the tinder is found to be on fire.

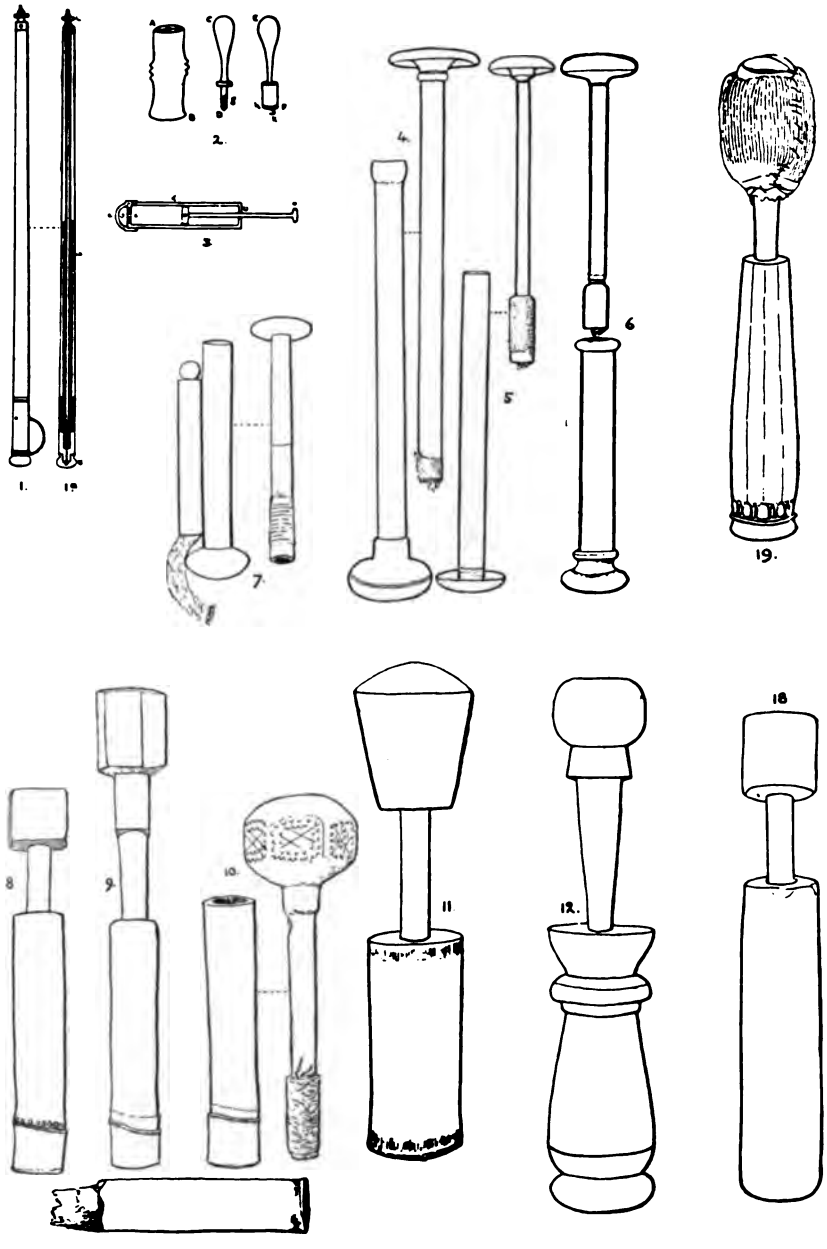
It will be noted that this instrument differs in one important particular from the ordinary fire piston of the physical laboratory. In the latter the air is merely compressed in the bottom of the cylinder, whereas in Lorentz's machine the air is not only compressed by the drive of the piston rod, but it is also forced under high pressure through a minute duct beyond which the tinder lies. The term fire syringe, so frequently applied to the various instruments for producing fire by air compression, seems to be peculiarly suited to this form, since the air is forced through a duct at the end of the main cylinder chamber, just as water is forced through the nozzle duct of a squirt or syringe. No doubt the air, already heated by the compression, gains additional heat from the friction caused by its violent passage through the small duct. It is possible that this instrument owes its origin to the observation of the flash produced by the discharge of an air gun, to which I have referred above, in addition to the scientific experiments as to heat generated by simple compression of air in a small space.

Fire pistons in which the duct was omitted appear to have enjoyed some favor upon the Continent, and to a lesser degree in England, during the early third of the nineteenth century. In the Mechanics' Magazine, Vol. XVII, 1832, p. 328, the following passage occurs:

The following is a sketch of a simple instrument for obtaining a light. As the invention, though not new [it is very well known on the Continent by the name of the instantaneous light-giving syringe. As it has not, however, been described in this work and may be new to some of our readers, we insert our correspondent's description.—Editorial note], is, perhaps, not generally known, I shall be glad to see this description of it in your magazine. * * * Yours respectfully, E. J. MITCHELL, June 19, 1832.

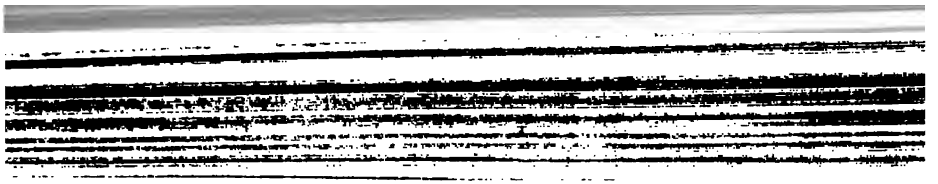
The description referring to the figures (fig. 2) I give in full:

AB is a brass cylinder, similar in appearance to a small brass cannon, having the hole rather better than three-eighths of an inch in diameter, drilled true and clean rinsed. CD is the form of a piston to work in the cylinder, but unpacked. EF is the same ready packed with thick leather and fitted up for use. H is a circular brass nut, working against the screw to keep the packing tight. K is a small hook, fastened in a hole drilled through the nut H. C is the handle to the piston and is made of wood. The method of use is described as follows: "Prepare some thin cotton rag (older and thinner the better) by steeping it in a solution of saltpeter, and drying it in a warm oven; tear a small piece off and place it on the hook K; introduce the piston EF into the cylinder AB a short distance only; then take the cylinder in the right hand, place it perpendicular upon the floor or a table, and strike the handle E with the ball of the right hand, so



FIRE PISTONS.

1–7, Europe; 8–12, 18, 19, Farther India.



that the piston may rapidly descend to the bottom of AB, and being *suddenly* withdrawn, the tinder will be found on fire, and will light a common brimstone match. *Amadou*, or German tinder, which may be obtained at any of the principal druggists, is likewise a good tinder, but I prefer the rag steeped in saltpeter.—E. J. M.

This instrument is of the simple air-compression kind, and, except for the piston rod terminating in a hook instead of a hollow for the tinder, it is identical in principle with the most prevalent form of fire piston.

In 1834 a notice occurs[a] of a French modification (fig. 3) of the type of instrument invented by Lorentz, referred to above, though from the following account it does not seem to have been very successful:

An attempt has been made in France to produce an instantaneous light by the compression of air. A strong tube A is furnished with a piston B, which may be driven rapidly from C to D by striking the knob E at the end of the piston rod. The end of the tube, at D, is pierced with small holes to allow the air, when forced up by the piston, to pass into the hollow space G, in the piece F, screwed air-tight to the end of the tubes. When a light is wanted a bit of tinder is placed in the hollow, the top screwed on, and the piston driven in forcibly; on unscrewing the top the tinder will be found ignited. Some modification of this instrument may be found useful, but in its present state it is inferior to the common tinder box; it requires considerable strength, is equally slow in getting a light, requires a match to be lighted after the tinder has taken fire, and is easily put out of order.

The method of squeezing the compressed air through ducts into a tinder chamber is very similar to that patented by Lorentz. The loss of time caused by the necessity for unscrewing the tinder receptacle after the tinder was ignited must have militated against the efficiency of these syringe-like forms. As far as I am aware none of them have been preserved, and this may be an indication that they never were numerous or extensively used. Specimens of the simple fire-piston form occur sparingly in museums and private collections. An example from Bedminster, Bucks County, Pennsylvania, said to date about 1815–1820, is mentioned by H. C. Mercer.[b] A specimen of brass from Gestrikland, or Helsingland, Sweden, is in the Nordiska Museum, Stockholm. Mr. E. Bidwell possesses three specimens, one of which (fig. 4) is entirely of brass and of large size, and resembles rather the modern instrument of the physical laboratory than the old domestic form. The tube is of thin brass, 8½ inches long by ⅜ inch in diameter. The other two (figs. 5 and 6), which may have been intended for domestic use, are smaller, of brass throughout, with the exception of the piston rods, which are of steel. In one (fig. 5) the lower end of the piston rod is packed with leather,

[a] The Penny Magazine, London, 1834, July 26, p. 286.

[b] Light and Fire Making, Philadelphia, 1898, p. 25.

while in the other (fig. 6) a brass piece accurately fitting the bore of the tube is screwed on, and no packing is required. All these have cup-like depressions at the end of the plunger for holding the tinder. Mr. Bidwell's specimens are all said to be English. It does not appear likely that the practical everyday use of these fire pistons was at any time very general, and the tinder box easily held its own against them, but it is worthy of note that a certain practical value was recognized for them, and even in quite recent years they were reintroduced in France, and a pocket form was sold by tobacconists in Paris. In these (fig. 7) the cylinder is of white metal with wooden knob, the plunger is of hard wood with cupped end, and fixed to the side of the cylinder is a tubular holder for the common cord tinder. A specimen given me by Mr. Miller Christy works very satisfactorily with a really "quick" form of tinder. Its reintroduction in western Europe was, no doubt, prompted rather by its peculiar interest as a scientific toy than by its being recognized as being of real practical importance. For ordinary purposes, as an appliance useful in everyday life, its death knell was sounded when the lucifer match became generally known. The latter, which has held its own unchallenged during the last seventy years or so, proved too strong and too severely practical a competitor, before which the time-honored tinder box, the fire piston, and the earlier chemical methods ("sulphuric-acid bottle," "phosphorus bottle," "promethian," etc.) had to give way.

THE FIRE PISTON IN THE EAST.

Interesting as is this fire-producing appliance as it occurs in western Europe in the form of a scientific instrument, and, to a limited extent, as a machine for domestic use, from an ethnological point of view, the interest of the fire piston centers mainly upon its occurrence in the east in an environment of relatively low culture. The problem is to ascertain whether this peculiar and very specialized method of fire production was introduced into the oriental regions from Europe, or whether it was invented independently by the little-civilized peoples among whom it is found as an appliance of practical everyday use. Either theory is beset with difficulties, which are likely to remain unsolved in the absence of early records. I shall revert later to the consideration of this question, and will now deal with the geographical distribution and varieties of the fire piston in oriental regions. Briefly stated, it may be said that the range of this instrument extends sporadically over a wide area from northern Burma and Siam through the Malay Peninsula and the Malayan Archipelago to its eastern limits in the islands of Luzon and Mindanao in the Philippines.

Burma.—In this region the fire piston is principally associated with the Kachin (Kachyen, Kakhyen, or Kakyen) people, and the forms vary as regards the materials used in their construction. The cylinders may be of bamboo, wood, or horn, the pistons or "plungers" are either of wood or horn, or are made of a combination of both materials. In all, the heat is produced by simple compression of the air in the tube, and I have seen no examples in which the air is forced through a duct.

Four examples were collected for me by my friend, Mr. H. E. Leveson, from the Kachins, on the Chinese border of the northern Shan States (lat. 24° 7′ N., long. 98° 15′ E.), nearly due east of Bhamo. These are interesting on account of their rude and simple structure. Each (figs. 8, 9, 10) consists of a natural tube of stout-walled bamboo, closed near the lower end by a natural node. The "plunger" is of wood, with a large roughly shaped head. One of the heads is hexagonal, each facet being decorated with chip carving (fig. 10). The lower end is cupped to form a receptacle for the tinder, and is packed with fine thread coated with wax (?). Two very similar specimens from the Shans of upper Burma are in the Ethnological Museum at Cambridge.

A better made example, though still composed of the same materials (fig. 11), was collected for me by Mr. Leveson from the Wa villagers in East Manglün (Mong-lem), on the Chinese frontier, 22° 20′ N., 99° 10′ E. The bamboo tube is neatly finished off, and the "plunger" is of very hard wood, with exceptionally large head accurately shaped. Another specimen in my possession (fig. 12) having a cylinder of bamboo is somewhat more pretentious, the cylinder being carved in a decorative form; the wooden "plunger" is unusually long and tapering. This example was obtained by Mr. Frank Atlay at the Ruby mines, Mogok, and kindly given to me. A small cloth bag containing vegetable-floss tinder belongs to this specimen, with which I have been able to produce fire with considerable ease on many occasions.

In the Ethnological Museum at Rome are several very rudely constructed examples of wood and horn, collected by Leonardo Fea from the Kachins (Cowlie Kachins) and Shans in the neighborhood of Bhamo, chiefly to the east of that town. These (figs. 13, 14, 15, 16 on pl. III) differ somewhat from the types most commonly seen from Burma. In all of them the cylinder is of stout buffalo horn, either light or dark colored, cut from the solid tip of the horn. In two of them (fig. 13) a pair of flanges are raised upon the surface near the top, and a carrying cord is knotted through these flanges. A similar pair of perforated flanges appear on a specimen in the Britis Museum. In these two examples the "plunger" is of hard wood

with expanded head cut from the solid (fig. 13). A third speci has a piston, with wide head cut from one solid piece of dark h Three others (figs. 14, 15, 16) and a fourth specimen (fig. 17) f the same district, given me by Prof. E. H. Giglioli, are peculia having the shaft of the plunger of horn, while the head is of w fixed by means of a stout rivet of horn to the shaft, which is wid at this point, and is tenoned into the head. The head in some con of a single piece of wood, in others it is in two pieces, and is r forced with bindings of string and cane. The riveted head seem be specially associated with the Kachins. The collector gives native name of the instrument as *caifo* or *caifoe*, and he adds remark that while these people are called Kachin by the Burn they describe themselves as Chimfo or Simpfo (i. e., "men"); name is also given as Chingpaw.[a]

A specimen (fig. 18 on pl. II) in my collection, obtained by Leveson from a Kachin on the Chinese border, from the same dis whence the ruder bamboo specimens were procured, has a cylind rough horn of a light color and a plunger, also very roughly mad black horn. Reference is also made by Capt. W. Gill[b] to the piston (with wooden cylinder) among the Kachins of the villag Pungshi (Ponsee), on the Taiping River, 50 or 60 miles eas Bhamo. John Anderson[c] describes and figures the instrument f the Kachins of the same region; it resembles that shown in fig. 1

Other specimens of the Kachin fire piston of which I have re are as follows:—

Two examples with plain horn cylinders, Berlin Museum.

One (referred to above) with horn cylinder, 8.7 cm. long, ha perforated flanges for a carrying cord; "plunger" of hard w riveted to rounded wooden head; given by Mr. R. Gordon to British Museum in 1873.

One given by Mr. R. Gordon to the Mayer collection, Liver Museum, 1874.

One of wood, Horniman Museum.

One with tapering cylinder of horn and wooden "plunger," Mr. E. Bidwell's collection.

One with tapering horn cylinder, 7.5 cm. long, piston of horn oned into a cubical wooden head and secured with a rivet; give Sir W. N. Geary to the British Museum, 1901.

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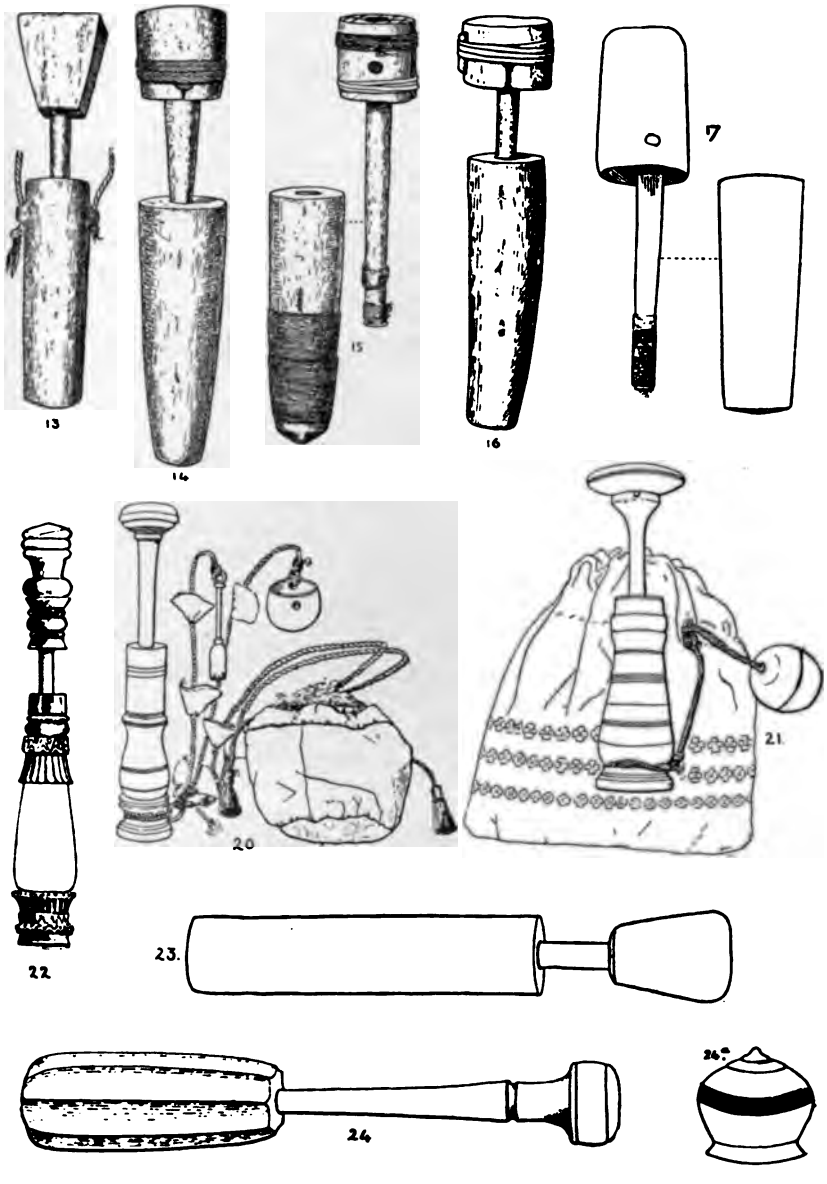
[a] H. J. Wehrli, Internat. Archiv f. Ethnographie, suppl. to Vol. XVI, 19 45. See also L. Fea, Quattro Anni fra i Birmanni e le tribù limitrofe. E. C. J. George, Memoirs on the Tribes inhabiting the Kachin Hills, Ce of 1892, Burma Report, I, appendices.

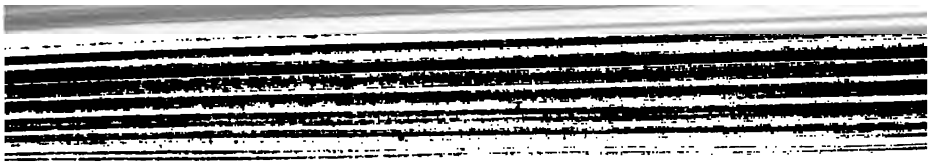
[b] The River of Golden Sand, 1880, Vol. II, p. 395.

[c] Mandalay to Momien, 1876, p. 134, and plate, figs. 3 and 4.



FIRE PISTONS.

13–17, 20–24a, Farther India.



One with cylinder of horn, 8.6 cm. long, tapering upward, cut in nine longitudinal facets, and with ring of carving round the base; plunger of hard wood with the head capped with silk wrapping; native name, *mi-put;* given by Capt. R. C. Temple to the Pitt-Rivers Museum, Oxford, 1890 (fig. 19).

One small though elaborate specimen of black horn throughout, apparently lathe-turned, the cylinder ornamentally shaped, and reinforced at the end with metal bands, as is also the rounded head of the "plunger;" from the cylinder hang three strings, one carrying a small velvet bag of vegetable-floss tinder, another a small nutshell containing grease for lubricating the packing of the piston, the third a small ivory spatula for spreading the grease (fig. 20 on pl. III); given by Maj. R. C. Temple to the Pitt-Rivers Museum, 1894.

From Mandalay, and probably of Kachin origin, I have in my possession a specimen very similar to the last, of black horn throughout, lathe-turned, the head of the piston riveted to the end of the shaft; with bag of vegetable-floss tinder, and small, spherical wooden grease box (fig. 21); given to me by the collector, Mr. H. O. Mordaunt, in 1899.

A sketch (fig. 22) of an elaborately carved fire piston seen in Mogok, 1893, was made for me by Mr. Donald Gunn. The decorative treatment of this specimen is unusually elaborate. The native name is given as *mizoon.*

Two examples, locally called *mi-put*, collected in the southern Shan states, were given me by Mr. H. E. Leveson in 1890 and 1891. Of these, one (fig. 23) is quite plain, with long cylinder of hard wood, and piston of buffalo horn with large rounded knob. It was obtained from a *pungi*, or priest in a monastery (*kyaung*). The other (fig. 24) is entirely of buffalo horn, the cylinder gracefully fluted in eight facets; the plunger is elegantly tapered, and has a rounded head inlaid with small metal studs. The depth of the bore in the cylinder is only 4.5 cm., the cylinder itself being 8.3 cm. long. This gives a very limited play to the piston, rendering the operation of fire producing a somewhat difficult one. Belonging to this specimen are a tinder pouch of palm spathe and a turned-wood box for grease (fig. 24 *a*).

Farther still toward the south a specimen was seen by Prof. A. Bastian, in a monastery in Shwegyin, which lies near the mouth of the Poung-loung River in Pegu. The tube was of ivory.[a] A similar specimen was made for him by a native.

It would appear that the westerly limit of distribution of fire pistons in Burma is bounded by the Irrawaddy River, while they extend in a north and south direction from the neighborhood of

[a] Bastian, Die Voelker des Oestlichen Asien, 1866, II, p. 418.

Bhamo to Rangoon. To the northeast they extend some distance across the Chinese frontier, among the eastern Kachins and peoples of mixed Kachin blood. On the eastern side of Burma they are found in both the northern and southern Shan states.

French Indo-China.—A piston (fig. 25 on pl. IV) in the Edinburgh Museum was obtained from the Khas (or Kumuks), an aboriginal hill tribe of low stature, inhabiting the country north of Luang Prabang, which lies on the Mekong River in lat. 20° N. It is entirely of horn; the cylinder is carved in an ornamental molding at either end. The piston has a knobbed head coated, apparently, with some kind of composition. A bag of cloth serves as a tinder pouch (fig. 25*a*).

Farther to the southeast the implement is again met with among the Moïs, a people of very low culture inhabiting the table lands and mountains between the Mekong River and the coast of Annam, from the frontier of Yunnan to Cochin China. They differ racially from the Annamese and Thai, and are said by Deniker[a] to belong probably to the "Indonesian" stock. A. Gautier describes[b] the instrument as having a cylinder of hard wood, with a bore of 7 to 8 cm. in depth, and 7 to 8 mm. in diameter. The piston, also of wood, has a large, rounded knob, and is cupped at the lower end for the tinder in the usual way. The tinder (*amadou*) is kept in a hard fruit shell hollowed out. The native moistens the end of the piston in his mouth, so as to lubricate it, and also to make the small piece of tinder adhere to the cupped hollow. Apparently the instrument is in constant use amongst the Moïs.

Malay Peninsula.—John Cameron frequently saw the fire piston in use among the Malays of the Straits, prior to 1865. He writes:[c]

> There is one peculiarity which I will mention, as it might, I think, be capable of improved application at home; it is the method adopted by some of obtaining fire. It is true that this is not the usual method, nor do I remember to have seen it alluded to by any other writer; I have witnessed it, nevertheless, repeatedly availed of by the Malays of the Straits; and in some of the islands to the eastward of Java, where I first saw it, it is in constant use. A small piece of horn or hard wood about 3 or 4 inches long and three-quarters of an inch in diameter is carefully bored through the center for three-fourths of its length, with a hole about a quarter of an inch in diameter. To fit this, a sort of ramrod or piston of hard wood is made, loose all along, but padded with thread or cotton at the point, so as to be as nearly air-tight as possible, when placed into the hole of the little cylinder. * * * When used, the cylinder is held firmly in the fist of the left hand; a small piece of tinder, generally dried fungus, is placed in a cavity on the point of the piston, which is then just entered into the mouth of the bore; with a sudden stroke of the right hand the

[a] Races of Man, p. 392.

[b] "Étude sur les Moïs," Bull. de la Société de Géographie Commerciale du Havre, 1902, pp. 95 and 177.

[c] Our Tropical Possessions in Malayan India, 1865, p. 136.

piston is forced up the bore, from which it rebounds slightly back with the elasticity of the compressed air, and on being plucked out, which it must be instantly, the tinder is found to be lighted. * * * I can only attribute the light produced to the sudden and powerful compression of the air in the bore of the cylinder.

This description of the method of using the fire piston applies practically to all oriental examples. The record is interesting as being an early reference to the use of the instrument in the peninsula, and also in the eastern Malayan Archipelago.

Turning now to more recent records of the occurrence of fire pistons in the peninsula, I may give the following first-hand information, which I owe largely to Mr. W. W. Skeat and to Mr. Nelson Annandale, who have done so much for the ethnology of this region:

Mr. Annandale, in 1901, saw the instrument in regular use at and in the neighborhood of Ban Sai Kau, a village in the state of Nawnchik (called Toyan by the Malays), the most northerly of the Siamese Malay states, west of the Patani River. The Siamese name of the fire piston is *lek phai tok*, the Malayan name is *gobi api*. It is there chiefly used for lighting cigarettes in the jungle, as the spark is not easily extinguished by high winds. One specimen from this village, given me by Mr. Annandale (fig. 26), is of very small size, the cylinder being only 5.7 cm. in length and the bore 4.5 cm. It is entirely of black horn; the cylinder is ornamentally, though roughly, turned, barrel-shaped in the center, and tapered to a blunt point at the lower extremity. The piston has a plain, rounded knob at the top, and the usual hollow for tinder at the other end. A specimen obtained there by Mr. Robinson for 5 cents is very similar in shape and size, though somewhat better made. A third specimen from the same locality (fig. 27), collected by Mr. Annandale for the Pitt-Rivers Museum, has a very elegantly lathe-turned and slightly engraved cylinder of horn; the piston is of light wood with a turned knob of horn through which it is fixed with an adhesive.

From farther south, in the state of Patani, Mr. Skeat procured three examples very similar in shape to those of Nawnchik; these are in the Cambridge Museum. One of them is very small (fig. 28), with horn cylinder and wooden piston; the depth of the bore is only 3 cm. A second has a lathe-turned horn cylinder and a piston of hard wood with ivory head, depth of bore 3.7 cm. The third (fig. 29) is larger somewhat, with lathe-turned cylinder of bone and wooden piston; depth of bore 5.5 cm. All three were obtained in Jalor (Jala), one of the seven districts of Patani, some 30 miles up the Patani River. The Malay name given by Mr. Skeat is *gobek api* (lit. "fire piston"). The word *gobek* is that usually applied to the piston (pestle and mortar) used by old and toothless men for crushing up the betel leaf; *api* in Malayan means "fire." The tinder,

rabok, is usually the fluffy substance obtained from the leaf bases of the *tukas* palm (*Caryota griffithii*), though occasionally it is obtained from other kinds of palm, or from rattan. Mr. Skeat tells me that the fire piston occurs throughout the interior of the old Malay state of Patani, or in other words, the subdistricts of Jala, Ligeh, Biserat, and Rhaman, and he also mentions that there is a probable extension northward and eastward into more distinctly Siamese territory. His specimens are practically identical with those obtained by Messrs. Annandale and Robinson in Nawnchik.

Mr. Annandale procured for the Pitt-Rivers Museum an example from the Samsam (i. e., Siamesing-Malay) village of Ban Phra Muang in Trang, on the west coast, c. 7° 25′ N., 99° 30′ E. This is the most northerly district in the peninsula from which I have definite record of a fire piston. This specimen (fig. 30) has a cylinder of light-colored horn, pointed and ringed below, as usual in the peninsula, the upper half roughly bound round with string coated with black wax. The piston is of black horn with rounded, carved knob, which is hollowed out as a receptacle for holding the supply of tinder. The depth of bore is 5.5 cm.

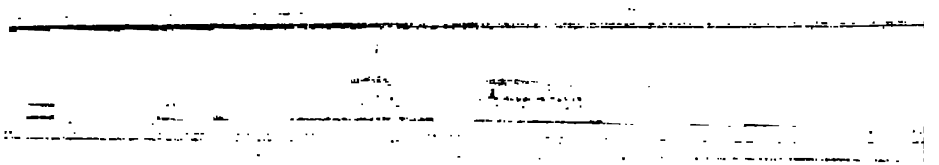
There are specimens in the Taiping Museum from the province of Perak, on the western side of the peninsula, but their exact locality is not specified, and I have no descriptions of them as yet.

An interesting aberrant type (fig. 31), now in the British Museum, was sent to Mr. F. W. Rudler in 1893 by Mr. Henry Louis. It was obtained by the latter in 1890 when in camp on a little stream known as Ayer Katiah, a tributary to the Teluban River. Presumably this is the Telubin River in the Siamese states of Saiburi or Telubin, the next river down the coast after the Patani River. In this the cylinder is of wood, 6.4 cm. long, neatly bound round with bands of plaited cane. The lower end is rounded off, instead of terminating in the point so characteristic of the peninsula. The piston, of hard wood, is very short, and has a large, roughly-carved head. The packing is of pale vegetable fiber. A large bean shell serves as a tinder box: it appears to be an *entada* bean (fig. 31 *a*). Mr. Louis related that a party of Malays came down from some neighboring *kampongs* (i. e., villages), and squatting down in camp, began to smoke, when one of the party, a young man, in the most matter-of-fact way, took out his fire piston and lit his cigarette. The particulars were kindly sent to me by Mr. Rudler.

It will be seen that the distribution of the fire piston is a very wide one in the Malay Peninsula, where it is found in the hands of both Malay and Siamese people, as well as among the mixed Siamese-Malays. The question arises whether the instrument is originally Malayan or Siamese. I have consulted Mr. Annandale and Mr. Skeat upon this point, and both are inclined to regard it as

FIRE PISTONS.

25–30, Farther India; 31–34, Sumatra; 35, 36, Sarawak.



of Siamese origin. The former writes to me as follows: "With regard to the *gobi api*, it is, so far as I am aware, a purely Siamese implement. I have never seen or heard of it in a purely Malay community. * * * There are specimens from Perak in the Taiping Museum, but their exact locality is not recorded, and even within a few miles of Taiping there is a large Samsam village, while the people of Upper Perak are indistinguishable from those of Rhaman and Kedah, being physically as much Siamese as Malay." Mr. Skeat informs me that, although the specimens which he obtained in Jalor were used by Malays, he is inclined to think that they are borrowed from the Siamese (or Siamesing-Malays), who appear to use them much more than the Malays do. "There are a good many Siamese and Samsams (i. e., Siamesing-Malays) in the district, and it is to their influence that I am inclined to attribute these fire utensils." Again he writes: "I have a strong belief that this particular object is Siamese, because it appeared to die out as we worked south into the more exclusively Malay districts, and I never came across any specimen of it in Kelantan or Trengganu (which are substantially Malay districts), any more than I did on the west coast, where Siamese influence was equally at a discount. My recollection is quite clear on the point that at Biserat in Jalor the fire piston was used by the Siamese more commonly than by the Malays, who appeared to have borrowed the idea from them."

I have not as yet seen or heard of any specimens of the fire piston from Siam proper, but it would be most interesting to know if they have been used there, and also to learn the details of their form, so that we may ascertain whether the types of the Burmese region can be linked by intermediate varieties with those of the Malay Peninsula.

I must now turn to the distribution of this interesting fire-making appliance beyond the southern limits of the peninsula.

Sumatra.—Van Hasselt[a] mentions the use of the fire piston by the Menangkabo Malays in the hinterland of Padang, on the west side of the island. The specimen which he describes (fig. 32) is of "karbouw" (buffalo) horn, and its native name is *tjatoew api bălantaq*. In form it reminds one of some Kachin types. Its size is large, and the plain surfaces of both cylinder and piston head are relieved with ring marks. The tinder, *raboewq* (cf. *rabok* in Jalor), is obtained from the *anau* palm. This specimen was obtained at Soepajang.

There is a specimen in the Berlin Museum from Padang on the west coast, but of this I have not full particulars.

Mr. R. T. Pritchett figures[b] an ornate example from Sumatra (fig. 33); he does not, however, specify the material or the size.

[a] Veth, Midden Sumatra, III, p. 177, and pl. LXXXIII, figs. 12 and

[b] Smokiana, 1890, p. 97.

There is a very fine specimen in the British Museum (fig. 34) which was collected by Carl Bock at Fort van de Capelle, Padang province, Sumatra. This example is elaborately carved out of horn. The cylinder is 8.2 cm. long and tapers slightly from above; it is decorated with bands of carving. The piston has a carved head which is surmounted by a well-shaped, rounded receptacle for tinder. This is very neatly fitted with a cap or lid which fits into the opening like a stopper, and is furnished on one side with a small projecting spur; in closing the lid this spur passes through a slot in the rim of the tinder receptable, and a half turn secures the lid in position (fig. 34 *a*). The name of this instrument is given as *tanar datar*, but it seems possible that there has been some confusion with Tanah Datar, the name of a place. At least this name requires verification.

Borneo—Sarawak.—In this island the fire piston is found principally in the hands of Malays and Sea Dayaks of Sarawak. In 1865, F. Boyle described[a] it as used by some of the Dayak tribes, and expressed much astonishment at the singular method of procuring fire. His description is evidently erroneous, but he adds, "I must observe that we never saw this singular method in use, though the officers of the *Rajah* seemed acquainted with it." He refers to lead being used as a material in making the instruments, and adds that "the natives say that no metal but lead will produce the effect."

Charles Brooke, in 1866,[b] writes as follows: "There is a method * * * used by the Saribus and Sakarang Dyaks for obtaining fire, which is peculiarly artistic, and from what direction such a practice could have been inherited is beyond my ken. The instrument is a small metal tube, about 3 inches long, closed at one end, with a separate piston, the bottom of which fits closely into the tube, and when some dried stuff answering the purpose of tinder is introduced, and the piston slapped suddenly down, the head of it being held in the palm of the hand in order to withdraw it as quickly as possible with a jerk, fire is by this means communicated to the tinder in the tube. The Dyaks call the instrument 'besi api.'"

W. M. Crocker asserts[c] that the fire piston is "found among the Saribus Dyaks only. Here we have a small brass tube lined with lead; no other metal, the natives say, would produce the same result. A small wooden plunger is made to fit the tube, the end of which is hollowed out in the shape of a small cup, in which is placed the tinder."

W. H. Furness also describes and figures[d] an example with lead-lined brass cylinder and wooden piston, from the Saribas Ibans (Sea

[a] Adventures among the Dyaks of Borneo, 1865, p. 67.

[b] Ten Years in Sarawak, 1866, p. 50.

[c] Journ. Anthrop. Inst., XV, 1886, p. 426.

[d] Home Life of the Borneo Head-Hunters, 1907, p. 170.

Dyaks), and in the British Museum there are two specimens from the Saribas district, also Sea Dyak. One was presented by Mr. G. D. Haviland in 1894, the other by Mr. Charles Hose. Both instruments have cylinders of lead-lined brass, 9 cm. and 9.8 cm. long, and pistons of hard wood. Mr. Hose's specimen has attached to it a bamboo box for tinder, the other has a tinder holder of *canarium* nutshell and also a small cleaning rod of cane and a metal spatula (? for grease). *Besi api* and *gochoh api* are given as the native names. These two examples closely resemble a specimen (fig. 35) presented by Mr. D. I. S. Bailey to the Pitt-Rivers Museum in 1904. It came from the Sea Dayaks of Simanggang, near Saribas. In structure it is identical with the others, and it has a tinder box of *canarium* nut and a brass pricker attached to it. Dr. A. C. Haddon brought back a very similar Saribas Dayak specimen, *guchu api*. Another example of the same form in the Kuching Museum, said to be from the *Kayans* but doubtless of Sea Dayak origin, is figured by both Lady Brassey[a] and R. T. Pritchett.[b]

Another type of fire piston in Sarawak differs from the above only in the fact of the cylinder being made of lead alone, instead of the lead being merely a lining to a brass tube. Mr. D. I. S. Bailey presented a specimen of this kind to the Pitt-Rivers Museum in 1904 (fig. 36). The cylinder has been cast evidently in a two-piece mold of bamboo, and is composed of a mixture of lead and tin. It is decorated with simple relief designs. The piston is of wood. Attached to the cylinder are a tinder box of *entada* bean full of palm-scurf tinder, and also a brass-wire pricker. It is a Sea Dayak specimen from Simanggang.

A nearly identical specimen was given to the Pitt-Rivers Museum in 1889 by Mr. S. B. J. Skertchley. It was made by a Kalaka (? Kalukah) native from the western part of Sarawak, not very far from the Saribas and Simanggang districts. Mr. Skertchley gives a detailed account of the instrument, to which I will refer readers for full details, and also an excellent figure.[c] The instrument itself, *besi api*, resembles the last in all essential details; a bamboo tinder box with palm-scurf tinder, a cleaning rod of cane, and one half of a bamboo casting mold accompany the specimen. Mr. Skertchley says that the metal of the cylinder is composed of two parts lead to one of tin. "It is cast in a bamboo mould. * * * The mould is a thin piece of bamboo, split lengthwise, on the interior of which the ornamental bands, etc., are incised. A piece of flat wood, plank by preference, has a hole made in it the size of the bore. Through this hole a rotan is pushed, which also passes through a lump of clay tempered with

[a] The Last Voyage, 1887, p. 148.

[b] Smokiana, 1890, p. 97.

[c] Journ. Anthrop. Inst., XIX, 1890, pp. 445–448, and pl. xi, fig. 1.

sand stuck on the upper surface of the plank. The rotan projects beyond the clay to a distance somewhat greater than the length of the cylinder. The mould, bound together with split rotan, is placed centrally and vertically over the projecting rotan, thus forming a box closed below with clay, open at the top, and having a rotan in the centre. Into this the molten metal is poured. When cool the rotan is withdrawn, the mold open, and the cylinder is complete. A good mould will make three or four castings, but, as a rule, the first destroys it. The measurements of the cylinder are: Length, 3¼ inches; width, ½ inch; bore ⅜ inch. This is the average size; larger ones do not work well; smaller ones are of no use."

British North Borneo.—The only actual specimen which I have from British North Borneo (fig. 37 on pl. v) was sent in 1890 by Mr. L. P. Beaufort, who collected it on the west coast, to Sir R. Biddulph Martin, who has very kindly given it to me. It is quite a remarkable and specialized form, unlike any other which I have seen from any part of the east. As in the last-mentioned examples from Sarawak, the cylinder is of lead, or possibly lead and tin, cast in a bivalve bamboo mold, and decorated at the lower end with faintly raised, foliated designs, and at the upper end with punched or incised zigzags. The great peculiarity of this example lies in the form of the lower end of the cylinder. The base, instead of being flat or rounded, is of unsymmetrical form and concave, and just above this is a broad, rounded notch on one side. From this notch a perforated duct communicates with the bottom of the bore of the cylinder, very much after the fashion of the touchhole and fire duct of an early muzzle-loading cannon. The presence of this duct is a most peculiar feature, and its *raison d'être* is not readily accounted for. It certainly recalls to one's mind those early European and English forms, in which the air is violently driven through holes, to which I have already referred, and it has occurred to both Mr. Miller Christy and myself that, possibly, the tinder was held in the outside notch against the small orifice, through which the air was violently driven in a compressed state by the piston, the friction due to passing through the small duct being largely responsible for the production of heat. At the same time I am disinclined to think that this was the case. The duct is, to my mind, far too large for the purpose, and it does not appear to have been enlarged at all since it was first made; through such a duct the air would escape so easily and quickly when forced through by the piston that there would be very little compression or friction, and, consequently, very little rise of temperature. The tinder, moreover, would almost certainly be blown away. It seems to me more likely that the tinder was placed, as usual, on the end of the piston (which is, indeed, hollowed out, cup-wise, in the usual manner, evidently with this intention), and that when the piston was driven forcibly

downward, the small orifice of the duct was tightly closed by a finger which would lie comfortably in the rounded notch. This would allow the air to be compressed, as the cylinder would thus be, temporarily, a closed one. At the end of the piston stroke, when the tinder was ignited, the finger would be raised, thus opening the duct, and, in addition to the piston being more readily and quickly withdrawn, through no vacuum being formed, the air from the outside, which would rush in through the open duct owing to the suction of the piston, would actually blow up the tinder into a higher state of incandescence, rendering it unnecessary to blow upon it after removal from the cylinder. I offer this theory as a possible solution of the mystery of this peculiar type, though as yet I have not been able to conduct experiments in order to see if such a process would act efficiently. The piston of this specimen is of wood, and presents the peculiarity of the cupped end having been capped with lead. This lead capping is damaged, and it is not easy to see whether it was intended to take the place of a packing or whether it was supplementary to the more usual packing of thread. No trace of thread packing is to be seen, though a sunken groove near the end of the pistons seems to be designed for holding some kind of packing wound round at this point. Mr. Beaufort told Sir R. B. Martin that fire pistons were becoming very difficult to obtain in British North Borneo, where they are confined to the west coast. He also added that "the better ones are made of *wood*."[a]

The only example made of wood from Borneo is one figured by C. M. Pleyte,[b] and, although this is not so stated, it seems likely that this may have come from British North Borneo. It is (fig. 38) quite plain, and differs in external detail from examples from Sarawak.

In regard to the general question of the presence of the fire piston in Borneo, it appears to be confined to an area extending from the westerly portions of Sarawak to the western coast of British North Borneo, though there is a wide hiatus in the distribution between these two regions. It is only found on or comparatively near the coast, where there is a strong admixture with the Malay element, and where Malayan culture is very evident. Both Mr. C. Hose and Mr. R. Shelford are strongly of opinion that this instrument has been introduced by the Malays, from whom the Sea Dayaks have borrowed it in comparatively recent times. Mr. Shelford wrote to me in answer to my inquiries that "the Malays and Sea Dayaks of the Saribas River were at one time associated a good deal in piracy, etc., and there was a good deal of intermarrying; at the present day the 'Orang Saribas' have more of the Malay in them than any other tribe of Sea Dayaks, and, as far as I can make out, they are the only

[a] Journ. Anthrop. Inst., XX, 1891, p. 331.
[b] Globus, LIX, pt. IV, p. 3 (of reprint), fig. 7.

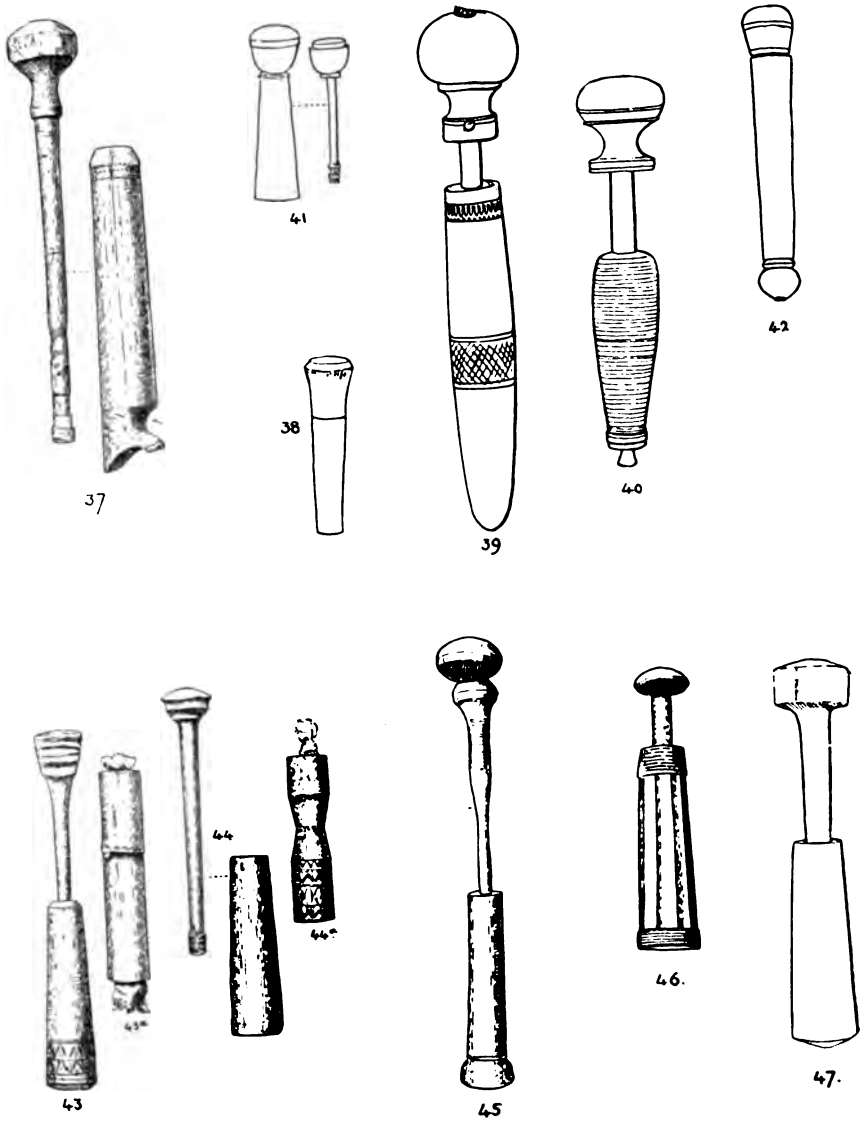
tribe who know the use of the *chelop* (i. e., fire piston)." The latter remark leaves out of consideration the occurrence of the implement in British North Borneo; but there, too, Malayan culture is not lacking on the coast, and it is likely that the forms found there, which differ from the Sea Dayak forms of Sarawak, are traceable to the same Malayan origin, the difference in type being due either to variation within the district or to different types of the instrument having been introduced by the Malays. The use of lead as a material is peculiar to Borneo, and it is possible that this may be a character developed in the island itself, unless the Malays may have themselves used this metal and introduced its use with the instrument itself. Of this there appears so far to be no record. There is no Siamese influence in Borneo, so that the direct influence of Siamese culture from the Malay Peninsula is quite improbable.

Java.—Fire pistons, though now scarce in Java, range over a wide area of the island. They are apparently always made throughout of buffalo horn; at least, all the specimines I have seen or know of are of this material.

A good, well-made specimen in my possession (fig. 39), of black horn carefully polished, has a cigar-shaped cylinder, with two bands of ornamental engraving. The piston terminates in a large rounded head, which is fixed to it with a horn rivet. This knob or piston head is hollowed out, and serves as a receptacle for tinder, which consists of a brown palm scurf. The specimen was obtained in Buitenzorg in the west of Java. This shape appears to be a characteristic one. Mr. C. M. Pleyte, of Leiden, had several examples of this form from Bogor, one of which is now in the Edinburgh Museum; these are almost identical with my specimens. In the museum at Rotterdam there is a horn fire piston from Java, but I do not know if its shape is the same as the above. In the Cambridge Museum may be seen a specimen from Kadiri (Kediri), in which the cylinder is shorter and terminates in a small projecting knob. It is ringed all over with transverse, incised lines (fig. 40). A different type again is figured by C. M. Pleyte,[a] in which the horn cylinder tapers from below upward, the base being broad and cut off square. The knob on the piston is hollowed for containing tinder, and is furnished with a lid which fits over a flange (fig. 41). In the same article Pleyte refers[b] to a Sundanese fire piston (West Java) called *tjĕlĕtok*. The form of this is, unfortunately, not described. He says that *tjĕlĕtok* is from the root word *tjetok*=Malay

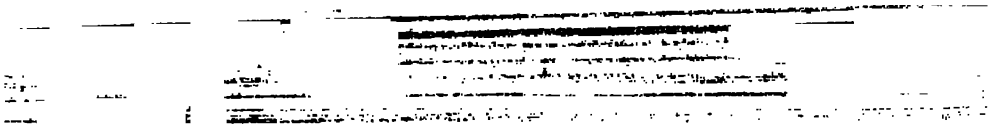
[a] Globus, LIX, pt. iv, p. 3 (of reprint).

[b] Quoting the catalogue of the Bataviaasche Genootschap van Kunsten en Wetenschappen, p. 56, No. 1120.



FIRE PISTONS.

37, 38, Borneo; 39–41, Java; 42, Flores; 43–47, Philippines.



tjatok; mentjatok=struck down quickly or with force. The word is the same as *tjatoew* given as the Malayan name of the instrument in Sumatra.

Flores.—From this island there is a fire piston in the Vienna Museum (fig. 42). It is made of horn, and is peculiar in having a rounded receptacle for tinder at the lower end of the cylinder, instead of in the knob of the piston.

John Cameron says, as quoted above, that prior to 1865 he saw the fire piston in use in some of the islands to the eastward of Java, so that we may assume that other islands in the neighborhood of Flores possessed the instrument at that time. Unfortuately, he does not specify the localities.

Philippine Islands.—The fire piston as it occurs in the Philippines appears to be restricted mainly to the wild non-Negrito tribes of north central Luzon, where it is used by natives of the so-called "Indonesian" group. It is also recorded from Mindanao, however. H. Savage Landor says:[a] "This instrument, called *Bantin*, generally made of carabao horn, is found among various tribes of North Luzon, and also in South Luzon, among the curly-headed Aetas of the Gulf of Ragay. * * *" He does not specify the particular tribes in the north, and it is unfortunate that he does not say if his information regarding the Aetas is first-hand or not. I have found no other references to fire pistons among tribes of Negrito stock, and further information is required on this point. A. E. Jenks remarks[b] that "the fire syringe, common west of Bontoc Province among the Tinguian, is not known in the Bontoc culture area." Others extend the distribution into the Bontoc area, and beyond it into the more central portions of the interior of North Luzon. Doctor Schadenberg mentions[c] their use by the Bontoc people, and describes the cylinder as of carabao (buffalo) horn tip, c. 9 cm. long with a bore of about 1 cm. The fire piston, together with a box for grease and tinder of charred cotton, is carried in a pouch woven from *bejuco*. He adds that the natives value them very greatly and require a high equivalent in exchange.

In the Dresden Museum there are two specimens. Of these, one, from the Igorrotes of Bontoc (fig. 43), has a cylinder of wood tapering from below upward; the other (fig. 44), from the Igorrotes of Tiagan, is very similar, but is made of horn. Each has a separate

[a] Gems of the East, 1904, II, p. 334.

[b] The Bontok Igorrot, Manila, 1905, p. 134. (Department of the Interior, Ethnol. Survey Publications, Vol. I.)

[c] Verhandl. d. Berliner Gesell. f. Anthrop., 1886, p. [551], in Zeit. f. Ethnol., Vol. XVIII.

tinder-holder of bamboo.[a] Another Igorrote example (fig. 45), collected by Dr. Alexander Schadenberg, is in the Vienna Museum. The cylinder is of carabao horn and the piston of wood; the tinder of cotton is contained in a bamboo holder. The collector refers to the use of the instrument among the Igorrotes of Tiagan, Lepanto, and Bontoc. F. H. Sawyer[b] gives the Igorrote name of the fire piston as *pamiguin*. *Sulpakan* is mentioned as the native name of a specimen from Luzon in the Berlin Museum. A Tinguian specimen is in the latter museum. In the Ethnological Museum at Rome there is a fire piston from the Calinga tribe in the province of Nueva Vizcaya, collected by José Ma. de Mourin, 1893 (fig. 46). The horn cylinder is longitudinally faceted and transversely ringed at either end. The piston is of wood. D. C. Worcester mentions[c] examples made of buffalo horn from the wild tribes of North Luzon. He adds: "To perform this operation successfully requires long practice. I have yet to see a white man who professes to be able to do it. * * * How the savages first came to think of getting fire in such a way is, to me, a mystery." I may assure him that the process of procuring fire by this means is quite easy, provided that the bore of the cylinder is true and the piston carefully packed. In Mr. Edward Bidwell's collection there is an example (fig. 47) from Luzon with horn cylinder and wooden piston, made very plainly. Mr. Landor[d] says that in the more elaborate fire pistons from Luzon "a receptacle for the tinder balls is to be found and a metal spoon attached."

Lastly, there is a reference to the fire piston in Mindanao, the southern island of the Philippine group. F. H. Sawyer mentions[e] it as being used by the Mouteses or Buquidnones in that island.

ORIGIN AND DISPERSAL.

Having given as far as my present information admits a description of the geographical distribution and varieties of the fire piston, let me now turn to the more difficult though perhaps more interesting side of my subject. The question arises, What do we learn as to the history of this instrument from its distribution?

The two regions in which it occurs are very widely separated, both geographically and culturally. On the one hand, we have western Europe and England as a home of the fire piston in an environment of the highest culture; on the other hand, we find it occurring over

[a] Publicationen aus dem Kgl. Ethnog. Museum zu Dresden, by A. B. Meyer and A. Schadenberg, VIII, Die Philippinen. 1. Nord Luzon, 1890, p. 21, and pl. XVII, figs. 18 and 19.

[b] The Inhabitants of the Philippines, 1900, p. 266.

[c] The Philippine Islands, 1898, p. 297.

[d] Op. cit.

[e] Op. cit., p. 345.

a very wide but very connected area in the east, amongst peoples relatively low in the scale of civilization. The primary question requiring solution is whether the fire piston has been transmitted from the one geographical area to the other, or whether it was independently arrived at in the two regions. We know that the principle of the method of producing heat by compression of air was discovered in England and France by scientific experiment, and that this principle was to some extent adapted to domestic use there, by the invention of the fire piston, so that it is at least clear that the European form was not derived from the east. Was, then, the eastern instrument a derivative from the western? This question is not easily answered. On the one hand, the difficulty of explaining how native peoples, in a comparatively low condition of culture, could possibly have arrived independently at the knowledge requisite for the invention of this method of fire production is so great as almost to compel the belief that the instrument must have been introduced from elsewhere by some more highly cultured race. It must be remembered that it is only one hundred years ago last February that the first English patent was taken out by Lorentz for a fire piston, and that the scientific knowledge of this method of obtaining a spark dates only from a very few years earlier. This, among a people in the highest state of civilization and of scientific advancement. It seems almost incredible that so delicate and far from obvious a method can have been discovered, whether by accident or by gradual development, by any of the eastern peoples amongst whom it has been found in use. At the same time, it must be admitted that this is the only serious difficulty which lies in the way of admitting the possibility of an independent origin in the two main regions of distribution. There is no inherent impossibility in such a double origin, cases of independent invention of similar appliances in widely separated regions having frequently arisen. There is no record of introduction by Europeans.

There are, furthermore, considerable difficulties in accounting for the dispersal of the fire piston in the east, under the theory of its original introduction from Europe. From the earlier references we learn that prior to 1865 the fire piston was already well known in the east over a very extensive geographical area, embracing Burma, the Malay Peninsula, Borneo, and the "islands to the eastward of Java." This is a wide range of distribution, and it would seem probable that considerable time would be required to account for this extensive dispersal, even if the instrument had been introduced by travelers from the west. If we choose to conjure up a picture of enterprising European voyagers in the earlier half of last century depositing supplies of fire pistons in various islands of Malay Archipelago and on the mainland of southeastern A

must also allow for the time which must have elapsed before due appreciation of the value and potentialities of the new machine would have been developed in peoples to whom its principle was hitherto absolutely unknown. We must also allow for a still longer period during which the difficulties of making imitations of the European instrument by native methods were gradually overcome; for we must bear in mind that, simple and few as are the essential elements which together form the fire piston, it is only when they are in perfect adjustment that the instrument will work effectively and produce the desired result. To this extent the fire piston is essentially a delicate instrument; an imperfect bore, faulty packing of the piston, or inferior tinder, will at once render the appliance practically useless. Native made and effective fire pistons were certainly widely distributed in the east before 1865. European travelers who observed them expressed great astonishment at this peculiar method of fire producing, which was evidently quite new to them. They were educated and experienced men, and we may gather from their marveling at the method that they were unacquainted with it at home, where the domestic use of the fire piston must have long since died out. Bastian, who records in 1866 that he had seen the fire piston in Burma, was born in 1826, and was therefore about forty years old at the time, and although his memory would have gone back that far into the early half of the last century, he was evidently unfamiliar with the instrument in Europe. It is unlikely, therefore, that the instrument was of at all recent introduction from Europe at that time. Another important point to be remembered is the fact that no fire pistons of European make have, apparently, been found in the eastern area of dispersal.

From the passage in the Mechanics' Magazine quoted above we may gather that in 1842 the fire piston was but little known in England, though it is said to have been familiar on the Continent. It appears on the whole unlikely that this instrument can have been taken out as a trade article to the east by English travelers later than, say, 1830, since its practical use, never very prevalent in England, seems to have been quite on the wane by that time. Nor is it likely that it would have been traded abroad much earlier than, say, 1815, since its first introduction to domestic use in England was no earlier than 1807. This would allow a probable maximum period of fifteen years during which English traders and travelers could introduce it to various parts of the east. The predominant European influences in those regions which are comprised within the area of dispersal of the fire piston in the east have been the English and the Dutch. Of the use made of the instrument by the Dutch, I have no record, but at least it would appear that they were not very vigorous in pushing this article in the Malay Archipelago, since such

large possessions as Dutch Borneo, Celebes, and the Moluccas, do not appear to have received the instrument. As to the French, who appear to have entertained a kindly feeling toward the fire piston and to have made fairly considerable use of it, they need hardly be considered as possible introducers, since the regions of geographical distribution of the fire piston in the east are mainly outside the sphere of their direct influence.

It is certainly difficult to account for the wide eastern distribution of the fire piston and the development of local native varieties by the theory of introduction from Europe, which allows so short a time in which to develop the conditions which already obtained prior to 1865. This is especially the case when we remember that such primitive and widely separated peoples as the Moïs of Indo-China and the Indonesian peoples of Luzon in the Philippines are well acquainted with the manufacture and use of the instrument. These peoples have until recently been very little known to Europeans.

It may be suggested that Europeans may have introduced the fire piston into some one or two districts only, and that the further dispersal was effected by transmission elsewhere through native agency. This would, however, have required a longer time than is available, as dispersal by this means is necessarily slow.

It has frequently been suggested that the Chinese must have originated and organized the dispersal of the fire piston in the east. It is a common practice to credit the Chinese with the invention of many strange things, but there is, unfortunately, no evidence whatever that they even knew of the fire piston, except perhaps on the Burmese and Siamese frontiers. At least, as far as I know, there are no records or specimens which give evidence of such knowledge on their part.

The geographical distribution of the fire piston in the Siamese Malay states and the Malayan regions of the peninsula has caused some of the distinguished local experts to believe that the instrument is rather Siamese than Malayan in origin, as far as that region is concerned. This theory would perhaps account for its northeasterly and northwesterly dispersal among the Moïs, the Shans, and the Kachins. It is possible that the Malays may have borrowed it from the Siamese. Be this as it may, the Malays have certainly acted, perhaps not as the sole, but at any rate as the main, dispersers of the fire piston over the islands of the East Indian Archipelago, from Sumatra to the Philippines. Wherever in this region the fire piston is found—even though it be in the hands of and manufactured by more primitive peoples—the influence of Malayan culture is also observable, and the instrument is not found in districts which are remote from Malayan contact. It is even possible that the Malays are the actual originators and that the Siamese may have borrowed the idea from them. Or the

evidence of its frequent use among the widely separated "Indonesian" or Proto-Malay tribes of Luzon and the Moïs of Indo-China, who are by some ethnologists classed as belonging to the "Indonesian" stock, together with the fact that the neighboring more highly cultured peoples are without it, may be taken as pointing to a Proto-Malayan origin, which would assign the invention of the fire piston to a race still lower in culture than the Malays proper. This theory would involve a very considerable antiquity for the Eastern fire piston and the probabilities are perhaps hardly in favor of it. All that can be said with any certainty is that, whether the fire piston was introduced to the Malays by Europeans or by some other Eastern people in a condition of culture more or less on a par with their own, we must, I think, give to the Malays due credit for having materially assisted in extending the geographical range of the instrument and of having introduced it into several of the islands of the Eastern Archipelago where it has taken root, and where local varieties have in the course of time arisen and themselves again become modified in matters of detail.

With the single exception of the peculiar type from British North Borneo (fig. 37), all the eastern forms are essentially the same in general structure, the less important details being those which alone are capable of modification and variation. These details include the materials used in the manufacture of the cylinder and piston, which may be of bamboo, wood, horn, ivory, bone, brass, or lead (lead and tin usually); the external form; such accessories as the tinder receptacle, which may be separate from the instrument, and consist of bamboo, nutshells, beans, palm spathe, or of woven materials. Prickers for adjusting the tinder, grease boxes and spatulæ for applying the grease to the piston packing, are other accessories which may be present or absent, but whose occurrence in identical shape in widely separated regions adds to the evidence which goes to prove that the whole series of eastern types belongs to one morphological group.

Assuming, for purposes of argument, that the oriental fire piston was invented independently by the relatively primitive peoples among whom it appears to have been in use during a long period, we may consider the question as to the manner in which these people might conceivably have hit upon this highly specialized method of producing fire. It must be admitted that the great difficulty in arriving at a satisfactory conclusion upon this point is the principal factor which militates against the acceptance of the theory of the native origin of the fire piston. There can be little doubt that, if the invention was made by an eastern people, the principle must have been arrived at by some happy accident, the effect having been produced during the process of some action or work unconnected with fire making. It is inconceivable that such a physical phenome-

non could have been thought out and elaborated scientifically by primitive peoples, and we may remember that in Europe the first appreciation of this phenomenon of heat production by air compression was due not to research but to observation of an unexpected effect. There are three absolute essentials necessary for production of heat in this manner: (1) A cylinder with accurate bore, closed at one end; (2) a piston accurately fitting the cylinder; (3) tinder which is very quickly inflammable. Therefore, in our search for prototypes, we are necessarily restricted to objects in which these elements may conceivably be associated.

A form of bellows used in blowing up the fire, which is very prevalent in Burma and many parts of the mainland and the Eastern Archipelago, and which belongs largely to Malayan culture, is constructed upon the principle of a piston; there is a cylinder and a packed piston, whose thrust drives the air out in a forcible manner. In this, however, a duct opens from the lower end, and since, therefore, the cylinder is not a closed one, there can be but little compression of the air; certainly not sufficient to cause a marked rise in the temperature. So that, even if by accident some tinder-like material adhered to the piston, it could not be ignited. In breaking through the nodes of a bamboo, in order to render the bore continuous and of greater holding capacity, a rod may be thrust violently down the cylinder, which at first is, of course, closed. Certain simple and primitive-looking fire pistons among the Kachins are indeed made of natural bamboo cylinders. It is unlikely, however, that the rod would fit so tightly as to act like a packed piston, and hence there would be next to no air compression. Appliances of the nature of toy popguns and water syringes are not unknown in the East, but although these exhibit some structural resemblance to the fire piston, there seems little likelihood of their having suggested the latter. The process of boring and gauging blowguns when these are made of solid wood might, conceivably, have led to some unintentional compression of the air within the bore, which might have caused the ignition of some responsive material adhering to the boring or gauging rod. While even this is improbable, it is interesting to recall that the distribution of the oriental blowgun embraces many of the regions where the fire piston is found. I have frequently had it suggested to me, that it is obvious that the fire piston must have been derived from the pestle and mortar so commonly used throughout the Indo-Chinese and Malayan area for crushing the betel nut or *chavica* leaves. In favor of this it may with truth be urged that there is often a very strong resemblance bet[illegible] appliances; indeed some of the small pestle and
Museum bear so striking a resem
pistons, e. g., the type shown in

carefully at the specimens in order to see to which group they belong. On the other hand, it is evident that the suggestion that the pestle and mortar is the prototype of the eastern fire piston is based solely upon this superficial similarity, which is evidently appreciated by the Malays, since they apply the word *gobek* to both instruments. We have only to remember that, for all practical purposes, characteristics which are essential to the efficiency of the one instrument are absolutely detrimental to that of the other. In the case of the betel mortar, it is imperative that the pestle should work *loosely* in the mortar, and it is equally essential that in the fire apparatus the piston should very accurately fit the bore. A slight departure from this rule in either case renders the instrument useless for its purpose, and it is, consequently, most improbable that either could have accidentally performed the function of the other and so have suggested it.

One other appliance seems to have a claim to consideration. In the process of cleaning the barrels of the small muzzle-loading cannons, such as are frequently seen in the East Indies, it is conceivable that in driving an accurately fitting cleaning rod up the bore with some force a considerable compression of the air inside might result, and that a piece of readily combustible matter might have been ignited thereby. The touchhole, being very small, might not have caused a too great diminution of the air pressure, since the air could only escape relatively slowly through this orifice; or on some occasions the touchhole may have been temporarily blocked, in which case the compression would have been greater and more effective.

In some respects this appears to be the least unlikely of the possible suggestions as to the prototype of the fire piston, and color is lent to the idea by the form of the North Borneo fire piston (fig. 37), in which the cylinder has the appearance of a miniature cannon actually fitted with a "touchhole."

At the best, however, I am not at present able to offer any very convincing suggestions as to how the fire piston may possibly have been discovered in its eastern home, and it seems all too likely that the question of its *monogenesis* or *polygenesis* may never be completely determined. The problem remains an exceedingly interesting one, both from technological and ethnological standpoints, and, in concluding this attempt to bring together the material available for comparative study, I may express the hope that further information may be forthcoming, both as regards the earliest records of the fire piston in the east and as regards the geographical distribution and varieties of this peculiar method of producing fire.

I wish to thank heartily those who have so kindly assisted me to procure specimens or information. More especially am I indebted to Messrs. Skeat, Annandale, Shelford, Leveson, Miller Christy, Joyce, and Bidwell, whose assistance has been of much value to me.

DETAILED DESCRIPTION OF ILLUSTRATIONS.

FIG. 1. Fire syringe, from patent specification of Richard Lorentz, 1807, No. 3007; printed 1856.

FIG. 2. Fire piston, from E. J. Mitchell, June 19, 1832, in The Mechanics' Magazine, XVII, 1832, p. 328.

FIG. 3. Fire piston, France. From The Penny Magazine, July 26, 1834, p. 268.

FIG. 4. Fire piston, England; of rolled brass; length of cylinder, 14 cm. For domestic use or for scientific experiment. E. Bidwell collection.

FIG. 5. Ditto, England; cylinder of rolled brass, 10.2 cm. long; piston of steel, 9.5 cm., with brass mounts and leather packing. E. Bidwell collection.

FIG 6. Ditto, England; cylinder of cast brass, 8.1 cm. long; piston of steel, 8.6 cm., with brass mounts; the packing is of brass. E. Bidwell collection.

FIG. 7. Fire piston, modern French; cylinder of white metal, 7.6 cm., with ebony knob; at side, a tube for cord tinder fitted with ball-and-chain extinguisher; piston of ebony, 7.8 cm. Purchased in Paris. Given by Mr. Miller Christy to author, 1902.

FIG. 8. Fire piston, Kachin, northern Shan states, lat. 24° 7′ N., lon. 98° 15′ E.; cylinder of bamboo, 8.1 cm.; piston of wood, 9.2 cm. Given by Mr. H. Leveson to author in 1898.

FIG. 9. Ditto, same data; cylinder of bamboo, 8 cm.; piston of wood, 13.1 cm.

FIG. 10. Ditto, same data; cylinder of bamboo, 8.5 cm.; piston of wood, 11.5 cm., carved head.

FIG. 11. Fire piston, made by Wa villagers on the Chinese frontier of East Burma, 22° 20′ N., 99° 10′ E.; cylinder of stout bamboo, 7.2 cm.; piston of hard wood, 10.9 cm. Given by Mr. H. Leveson to author in 1900.

FIG. 12. Fire piston, Ruby Mines, Mogok, Burma; cylinder of lathe-turned bamboo, 8.9 cm.; piston of wood, 16 cm. Obtained by Frank Atlay and given by him to author in 1907.

FIG. 13. Fire piston, *Kaifo*, Cauri Kachins, east of Bhamo, upper Burma; cylinder of light-colored horn, c. 7.6 cm.; piston of wood, c. 9.5 cm. Collected by Leonardo Fea, 1885; Ethnological Museum, Rome [40232].

FIG. 14. Ditto, same data; cylinder of black horn, c. 8.5 cm.; piston of horn riveted to wooden knob. Fea collection; Ethnological Museum, Rome [40233].

FIG. 15. Ditto, Kachins of mountains east of Bhamo; cylinder of black horn, c. 8.2 cm.; piston of horn riveted to wooden knob. Fea collection; Ethnological Museum, Rome [40235].

FIG. 16. Ditto, Kachins and Shans in mountains east of Bhamo; cylinder of black horn, c. 9 cm.; piston of horn riveted to wooden knob. Fea collection; Ethnological Museum, Rome [40472].

FIG. 17. Ditto, Kachin (Simpfo), Bhamo district; cylinder of black horn, 7.9 cm.; piston of horn riveted with horn to wooden knob, 12 cm. Fea collection, 1885; given to the author by Prof. E. H. Giglioli, 1903.

FIG. 18. Fire piston, obtained from a Kachin on the Chinese border of the northern Shan states, 24° 7′ N., 98° 15′ E. Collected by Mr. H. E. Leveson, 1898, and given to the author.

FIG. 19. Fire piston, Kachin, Upper Burma; carved cylinder of black horn, 8.6 cm.; piston of hard wood with knob wrapped in silk, 13.3 cm. Collected by Capt. R. C. Temple and given by him to the Pitt-Rivers Museum, 1890.

FIG. 20. Fire piston, Kachin, Upper Burma; lathe-turned cylinder of black horn with silver mounts, 6.3 cm.; turned piston of horn with brass-ringed knob; attached to it are a bag of velvet and silk containing vegetable-floss tinder, a grease box of nut shell, and an ivory spatula for grease. Collected by Maj. R. C. Temple and given to the Pitt-Rivers Museum, 1894.

FIG. 21. Fire piston, Mandalay, Burma; lathe-turned cylinder of black horn, 6.4 cm.; piston of horn riveted to turned horn knob; attached to it are a cloth bag with vegetable-floss tinder, and a spherical, lathe-turned wooden box for grease. Given by Mr. H. O. Mordaunt to the author, 1899.

FIG. 22. Fire piston, Ruby Mines, Mogok, Burma. Collected by Mr. Frank Atlay. From a sketch by Mr. D. Gunn.

FIG. 23. Fire piston, *mi-put*, obtained from a *pungi* at a monastery, southern Shan states; cylinder of hard wood, 11.9 cm.; piston of black horn, 13.1 cm. Collected by Mr. H. Leveson and given to the author, 1890.

FIG. 24. Fire piston, *mi-put*, southern Shan states; cylinder of black horn gracefully fluted, 8.5 cm.; piston of black horn with knob inlaid with metal pins, 15.5 cm.; furnished with a tinder pouch of palm spathe and a turned wooden grease box (fig. 24 *a*). Collected by Mr. H. Leveson and given to the author, 1891.

FIG. 25. Fire piston, Khas or Kumuks, north of Luang Prabang, Siam; cylinder and piston of horn, with bag of vegetable-floss tinder. Science and Art Museum, Edinburgh.

FIG. 26. Fire piston, *gopi api* (Malay) or *lek-phoi-tok* (Siamese), Ban Sai Kau, Nawnchik, Patani, Siamese Malay states; turned cylinder of black horn, 5.7 cm.; piston of horn, 6.5 cm. Collected by Mr. Nelson Annandale and given to the Pitt-Rivers Museum, 1902.

FIG. 27. Ditto, same data; cylinder of dark horn, lathe-turned, 8 cm.; piston of wood fitting into horn knob. Annandale collection; Pitt-Rivers Museum.

FIG. 28. Fire piston, *gobek api*, obtained from Malays in Jalor, Patani, Siamese Malay states; cylinder of light horn, 6.3 cm.; piston of wood. Collected by Mr. W. W. Skeat; Cambridge Museum.

FIG. 29. Ditto, same data; cylinder of turned bone, 9.5 cm.; piston of wood.

FIG. 30. Fire piston, from the Samsam village of Ban Phra Muang, Trang, Siamese Malay states; cylinder of light horn, lathe-turned, 7 cm.; piston of turned black horn with knob hollowed out for holding tinder, 7.8 cm.; Annandale collection, 1901; Pitt-Rivers Museum.

FIG. 31. Fire piston, obtained by Mr. Henry Louis on the Ayer Katiah, a small tributary to the Teluban River (this presumably is the Telubin River in Patani), Malay Peninsula; cylinder of wood covered with cane-work rings, 6.5 cm.; piston of hard wood; tinder box (fig. 31 *a*) made from an *entada* bean. Given by Mr. F. W. Rudler to the British Museum, 1901.

FIG. 32. Fire piston, Malays of Soepajang, Menangkabau, Sumatra; made of buffalo horn, cylinder c. 11 cm. long; copied from Veth, "Midden Sumatra," 1877–1879, pt. 2, pl. LXXXIII, figs. 12 and 13.

FIG. 33. Fire piston, Sumatra; copied from R. T. Pritchett, "Smokiana," p. 97.

FIG. 34. Fire piston, Fort van der Capelle, North Padang, Sumatra; carved cylinder of dark horn, 8.2 cm.; piston of horn, carved, and with knob hollowed out for tinder and fitted with lid which, with a half turn, can be secured by a projection which passes through a notch (fig. 34 *a*). Collected by Mr. Carl Bock; British Museum.

FIG. 35. Fire piston, *gochok api* (Malay), *pantang besi api* (Sea Dayak), Sea Dayak, Simanggang, West Sarawak; cylinder of brass, lined with lead, 9.1 cm.; lathe-turned piston of wood; *canarium* nut with vegetable tinder and brass pricker attached. Collected by Mr. D. I. S. Bailey, and given by him to the Pitt-Rivers Museum, 1904.

FIG. 36. Fire piston, same data; cylinder of lead (or lead and tin) cast in bamboo mold, 8.1 cm.; carved piston of hard wood, 11.6 cm. Bailey collection, Pitt-Rivers Museum, 1904.

FIG. 37. Fire piston, west coast of British North Borneo; of very unusual construction; cylinder of lead (or lead and tin), cast in bamboo mold, with lateral notch on one side at lower end, from which a duct leads to the bottom of the bore in the cylinder; length of cylinder, 10.3 cm.; piston of wood, 13.5 cm., capped with lead at the lower extremity. Collected by Mr. P. Beaufort, 1890; given by Sir R. Biddulph Martin, Bart., to the author, 1907.

FIG. 38. Fire piston, Borneo: of wood. Copied from C. M. Pleyte, "Indonesisches Feuerzeug," Globus, LIX, No. 4.

FIG. 39. Fire piston, Buitenzorg, west Java; of black horn; cylinder, 10.6 cm., engraved; piston riveted to knob, which is hollowed out for vegetable-floss tinder. Collected by Mr. C. M. Pleyte; author's collection.

FIG. 40. Fire piston, Kediri, east central Java; of black horn; cylinder, 7 cm. Cambridge Museum; figure taken from facsimile belonging to Mr. E. Bidwell.

FIG. 41. Fire piston, Java; of buffalo horn; the knob of the piston hollowed and fitted with lid, forming a tinder-box. Copied from C. M. Pleyte, "Indonesisches Feuerzeug," Globus, LIX, No. 4.

FIG. 42. Fire piston, Flores Island, East Malayan Archipelago; made of horn; cylinder fitted with tinder receptacle at lower end. Vienna Museum; from a rough sketch.

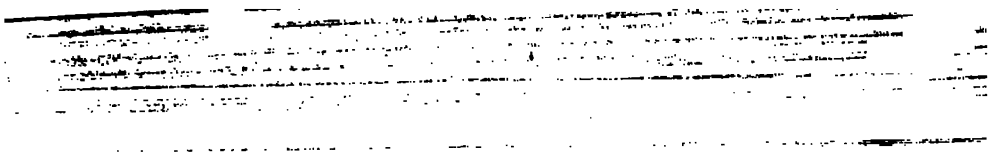
FIG. 43. Fire piston, Igorrotes of Bontoc, North Luzon, Philippine Islands; of wood, engraved; piston of wood; tinder holder of bamboo, 10 cm. Collected by Herr C. Semper; Dresden Museum; copied from A. B. Meyer, Publ. a. d. Königl. Ethn. Museum zu Dresden, VIII, pl. 17, fig. 18.

FIG. 44. Fire piston, Igorrotes of Tiagan, North Luzon; of buffalo horn; cylinder, 8.8 cm.; piston, 12.7 cm.; engraved bamboo tinder holder, 8 cm. Semper collection, Dresden Museum; copied from same source, fig. 19.

FIG. 45. Fire piston, Igorrotes of Tiagan, Lepanto and Bontoc, North Luzon, cylinder of buffalo horn; piston of wood; a bamboo holder with cotton tinder belongs to this. Collected by Dr. Alexander Schadenberg, Dresden Museum (30313); copied from a sketch kindly made by Irene Rust of Vienna.

FIG. 46. Fire piston, Calinga tribe, Nueva Viscaya, North Luzon; faceted cylinder of horn, c. 6.3 cm.; piston of wood. Ethnological Museum, Rome (49164); from a rough sketch.

FIG. 47. Fire piston, Luzon, Philippine Islands; cylinder of black horn, 7.5 cm.; piston of wood. E. Bidwell collection.



THE ORIGIN OF THE CANAANITE ALPHABET.[a]

By Franz Prætorius.

Soon after the year 1000 B. C. there appeared in Canaan a system of writing which has been very incorrectly called an alphabet, that is, a phonetic writing which resolves even the simple syllable into its component parts. With this reservation, however, for the sake of brevity, the system will herein be referred to as the Canaanite alphabet.

It is well known that the Canaanite alphabet quickly conquered the world, but its definite origin has been shrouded in obscurity. There has been no lack of effort to derive this alphabet from older and more complicated oriental systems, but this has not been successful. Other methods of explanation have likewise led to no result.

Canaan's northern frontier borders the territory of the Hittite inscriptions, while opposite the coast of northern Canaan is the island of Cyprus, where, down to the time of Alexander the Great, there survived in the "epichorial," or native, syllabic writing, an especially pure phonetic system. There is a common tendency to derive this Cypriote syllabic system from the Hittite pictures. It is probable, however, that systems akin to Cypriote writing once spread over all of Asia Minor, as evidenced in the Greek alphabet in the exotic admixtures from some of the peoples of Asia Minor.[b]

Thus considering the geographical position of these countries, the syllabic writing of Asia Minor and Cyprus might have been the source of the Canaanite alphabet. There are other reasons of a general character that may be adduced in favor of this possibility. Is the Canaanite system really an alphabetic one as it is commonly called? I believe that upon close observation this question will have to be answered in the negative. It is really a syllabic system like the Cypriote, except that some of the Canaanite signs have the value of simple consonants only, as in the Cypriote. In Canaanite we have קטל, i. e., Ka-ta-l, just as the same group of sounds would be written

[a] Translated, by permission, from the German of Franz Prætori Ueber den Ursprung des kanaanaeischen Alphabets. Berlin, Reuther und I nard, 1906.

[b] See Sayre in Schliemann's "Ilios," pp. 766 ff., and in T the Society of Biblical Archeology, Vol. IX, pp. 112

in Cypriote, 8 ⊢ T i. e., Ka-ta-l. And just as the Cypriote writing has only such syllabic signs (aside from the five vowels) as express the combination of a consonant with a succeeding vowel, so also in the Canaanite ק is ka, not ak. Signs for composed (closed) syllables (bak, daf, etc.) are used in neither, nor are double consonants considered in either. In Canaanite we find קטל, i. e., ki-(t)te-l, and in Cypriote Z + ϙ ∗, i. e., *'Α-πό-(λ)λω-νι*. Finally, the Canaanite reads from right to left just as does the Cypriote.

I am unaware whether anyone has heretofore thought of the possibility of the Canaanite alphabet being dependent upon the Cypriote syllabic writing, but certainly no attempt has been made to follow up this theory; for what Roeth adduced in this direction in Die Proklamation des Amasis an die Cyprier, pp. 1 ff, may, in my opinion be passed over.

The Cypriote syllabic writing is by no means perfect and definite. This it can not possibly be, since it has signs only for open syllables and nothing else, and it is therefore necessary to employ syllabic signs to indicate consonants. Each Cypriote syllabic sign is equivocal, inasmuch as it can express both a certain open syllable and also merely the initial consonant of such syllable. Certain rules have developed on this point (which need not be detailed here), but these only operate when, for instance, the syllabic sign "po" is to be used for "p," and not for the syllabic sign "pi" or "pa," but they do not definitely indicate that "p" alone is to be pronounced, and not "po." This can be determined only by a knowledge of the Greco-Cypriote dialect. So, for instance, we find ꞉⊥FΛ, i. e., po-to-li-ne, but only through a knowledge of the language and of the context do we learn that these syllabic signs are to be combined into *πτόλιν* (ptolin), and not into ptoline. To one who is not an expert in Cypriote writings it will be of little use to state that in this word only the syllabic signs "po" and "ne" should be used for the consonants "p" and "n" alone. In the same manner it can not be inferred from the writing alone that ꞉ F ⊥ M i. e., mi-si-to-ne is to be understood as *μισθῶν* (misthon), or Ш ⊢ Ш Ψ ⊥ i. e., ka-te-se-ta-se, as *κατέστασε* (katestase) the rule also prohibited the employment in these words of other syllabic signs than "si," "ne," and "se" for the consonants *σ*, *ν*, and *σ*.

We learn from fixed academic rules that the Cyprians of Greek tongue, or perhaps even those inhabitants of Asia Minor from whom the Cyprians had received their syllabic writing, had so far progressed in discerning the component parts of the syllable that they took the first groping step to pass from the syllabic writing to the alphabet. To be sure, they already had in the signs for the five vowels, a, e, i, o, and u, signs for five simple sounds; but as a matter of fact they employed these vowel signs only where the vowel in itself

constituted a syllable, so that the Cypriote vowel signs equaled, in the frequency of their use, all the syllables. So, in the Cypriote system also, the second components of a diphthong were as important as a syllable-forming vowel.

It can hardly be assumed that it was the identical Cypriote known to us that was adopted and modified by the Canaanites, but it was probably an earlier form, akin to the present one, that they must have received from Asia Minor. But as we do not know this older form we must begin our investigation from the Cypriote. We may assume, on the ground of the Cypriote pattern, that the Canaanites likewise discerned in the system of syllabic writing received by them the idea of the pure consonant, and also the possibility of each syllabic sign being used merely for the initial consonant of the syllable. Hence started the transforming and value-changing activity of the Canaanites.

In Cypriote five syllabic signs were formed from each consonant. For instance, from p were formed pa, pe, pi, po, and pu, each of which could also merely signify p. The Canaanites, however, limited the number of syllabic signs to one. Thus for pa, pe, pi, po, pu, and p only one sign was chosen.

If I am not mistaken, the ambiguity and indefiniteness already existing in Cypriote were carried to a complete uniformity or simplicity when the writing was carried over into a foreign language, since it became necessary to give some of these syllabic signs particular sound values, partly such as were not represented at all in the Cypriote-Greek language, partly such as the Cypriote writing did not distinguish from other similar sound values. In consequence of this a considerable number of the old syllabic signs were used up. Since the Canaanites retained only one sign for all the open syllables attached to one and the same consonant and for the consonant itself, so the element common to all its applications, that is, its merely consonantal value, became very prominent in this sign. It seems as if the Canaanites created an alphabetic system while syllabic writing still existed, only to its great loss, because the new form was more indefinite. And yet, it must be said that it had the advantage of being simpler, and the overwhelming success of the Canaanite system shows that this advantage was much greater than the loss.

Upon the basis laid by the Canaanites with this apparently alphabetic system it was easy for the Greeks to create with a single stroke, as it were, a genuine alphabet. Semitic peoples, on the other hand, made various attempts to check the indefiniteness and ambiguity of the Canaanite system, but in principle they have not yet passed beyond the syllabic stage.

Passing now to a detailed discussion of the origin of the Canaanite signs from the Cypriote, we must again recall that since in Cypriote

five syllabic signs are attached to each consonant, it would not be uncommon to find here and there a certain similarity to a Canaanite sign with a corresponding sound. This aspect was also pointed out by Arkwright in his unsuccessful attempt to derive the exotic portions of the Lycian alphabets from Cypriote forms: "In spite of the very large range of comparison afforded by a syllabary in which every consonant appears in five distinct forms," etc.[a] This abundance of signs is offset by some serious deficiencies. In the first place, the Cypriote writing does not distinguish between k, k^h, and g, t, t^h, and d, p, p^h, and b. In transcribing Cypriote signs the conventional usage is to employ merely k, t, and p. Futhermore, the Cypriote writing has but one surd sibilant and no gutturals at all. But fortunately our discussion is only made easier by these deficiencies; for in the five syllabic signs for k, k^h, and g we may look for the Canaanite k as well as for the Canaanite g, and in the five syllabic signs for t, t^h, and d we may look for the Canaanite t as well as for the Canaanite d, etc. And to what can we attach the origin of the gutturals?

Notwithstanding the great danger of deceptive coincidence, it nevertheless seems to me that some Canaanite characters exhibit such a great resemblance to Cypriote signs of a corresponding sound that I wonder why nobody, so far as I know, has yet called attention to it. I repeat here that in all probability it was not the Cypriote system that we know that came to the Canaanites, but an earlier form of the same family of writing systems, so that it is quite natural that we should be able to follow only in part the process of adaptation and development. As a possibility, though a remote one, I would mention that the origin of the Canaanite alphabet in its entirety should be looked for somewhere else, though the Cypriote system of Asia Minor may have supplied it with a large contingent, just as such contingents from it entered into the Greek alphabet of the peoples of Asia Minor.

I begin with the vowel signs. In the same degree that the Cypriote writing makes little distinction between long and short open syllables, so there is little distinction between signs for long and short vowels. It has only the quantitatively indifferent vowel signs a, e, i, o, and u. Nor does it add these vowel signs to a syllabic sign of an open syllable ending in a, e, i, o, or u, in order to thus mark such an open syllable as a long one. In fact, the use of these vowel signs is very limited; they are employed only when the vowel begins a syllable, that is, when the vowel sign is at the same time the sign of an open syllable. The signs i and u are used, besides, as second components of a diphthong, which components are considered in the Cypriote system of writing as separate open syllables. Examples of the use of the

[a] Jahreshefte des oesterreichischen archaeologischen Institutes, vol. 2, p. 74.

vowel signs: 𐤀𐤌𐤍𐤊𐤋, i. e., *a*-mu-ko-lo-*i*=Ἀμύκλωι (Amykloi) 𐤌𐤀𐤍𐤀𐤌𐤄𐤍𐤄𐤀𐤔𐤄𐤉𐤅𐤓𐤊𐤔𐤉𐤀𐤔𐤄, i. e., me-ma-na-me-no-*i* | *e-u*-we-re-ke-si-*a*-se=μεμναμένοι εὐϝεργεσίας (memnamenor euvergesias); 𐤀𐤉𐤅𐤉, i. e., *a-i*-we-*i*=αἰϝεί (aivei); 𐤌𐤀𐤕𐤄𐤉𐤔, i. e., te-*o-i*-se=θεοῖς (theois).

Since the Canaanites modified the Cypriote syllabic writing to the extent that for the five open syllables inherent in a consonant and for that consonant itself they retained only one sign, it was but consistent that for all the five syllables not inherent in a consonant, for all the five syllables which begin with a vowel, and for all the syllable-forming vowels they likewise retained only one sign. Five monophone syllabic signs between exclusively polyphone signs would have been too great a contradiction. The Canaanites obtained this polyphone sign for the syllable-forming vowels from the Cypriote 𐤀, i. e., a.

The sign for a in Cypriote is 𐤀, that is, a six-pointed star, the vertical stroke of which usually rises considerably above the others. 𐤀 is the prototype of the Canaanite 𐤀. In order to write the Cypriote 𐤀 the pen had to set in thrice; the sign was therefore cursively abbreviated by beginning above to the right and writing the two nonvertical points of the star in a single stroke. As a result the picture of the star was defaced. Whether the beginning of this cursive transformation was already made in Asia Minor, Cyprus or in Canaan we can not know.

By employing the Cypriote syllabic sign for *a* as a polyphone sign for syllable-forming vowels in general (𐤀, 𐤀, 𐤀, 𐤀, and 𐤀 = a, e, i, o, and u), the Canaanites achieved something besides. They learned through this mode of writing, something which was perhaps especially suggested to them by the phonetic system of all the Semitic languages—that every vowel which begins a syllable is introduced or can be introduced by a very weak consonant, such as the Arabic *hamza;* they gained through this mode of writing an understanding of this weak consonant itself. 𐤀 (𐤀) was for them no more a polyphone vowel sign, but became a syllabic sign for *hamza* with inherent a, e, i, o, and u, and also a sign for mere *hamza*. The uniformity of the Canaanite system of writing was not broken up: 𐤀 stood on the same level with 𐤁, 𐤂, 𐤃 (b, g, d), etc.

I consider it merely a coincidence that the 𐤀 migrated then as *α* (a) to the Greeks. It certainly has nothing to do with the original Cypriote sound value, for the sound value of the sign in Greek was rather the name of the character; the name *alef* pushed aside other possibilities, and the sound value of a was logically (that is, after the first letter of the word) established, the *hamza* not bei felt or bei

deliberately neglected. In the same manner originated the sound value of E, H, and O.

The Cypriote vowel signs for e and o do not seem to have found a place with the Canaanites. But we unmistakably recognize the presence of the Cypriote i and u with the Canaanites. I shall in the first place discuss the origin of the Canaanite forms from the Cypriote.

The sign for i in Cypriote is 𐠊. The vertical insertion in the four-rayed star is sometimes more or less bent toward the upper right ray 𐠋; in some places we also met with the form 𐠌, in which the vertical insertion is so inclined as to be parallel with the upper left ray. In this 𐠌 I discern the prototype of the Canaanite 𐤆. In order to write the Cypriote 𐠊, the pen had again to set in thrice as in the ✳. The sign was cursively abbreviated by first forming the vertical insertion with the slanting bar running from right above to left below in one stroke, 𐠍. Here, too, we do not know where this transformation was first effected, but it may be surmised that the above-mentioned secondary forms 𐠌 and 𐠋 were already preliminaries to the cursive 𐠍. This cursive 𐠍 was then modified into 𐤆. In this last development, as exhibited by the Canaanite alphabet, the tendency toward cursive writing is likewise unmistakable. For after the ray to the right below was adjoined to the principal bar, the hand had to hasten toward the left side to write the next following letter in order to finish the last ray, i. e., that to the left above.

The sign for u in Cypriote is 𐠎, 𐠏, 𐠐 and similar forms. Here the identity with the Canaanite 𐤉 is evident; only that in the latter an older phase of graphic development seems to be preserved. In Greek 𐤉 became Γ and υ which is nearer the Cypriote form.

The Canaanite use of the two-vowel signs agrees with that of Cypriote in so far as they serve to express diphthongs; so, for instance, in the Moabite (Mesha) Stone בימי בביתה (bimai, bebaithah). I shall, however, not assert that this Canaanite use of 𐤉 and 𐤆 is directly connected with that of Cypriote, neither shall I deny it. In fact, I leave the question of the oldest use of the matres lectionis (the vowel letters) entirely aside.

In their polyphone system the Canaanites had the same trouble with the monophone syllable-forming vowels 𐤆 and 𐤉, as they had with the 𐤀. In the same way that they changed the value of 𐤀, as shown above, so they also changed that of 𐤆 and 𐤉. Of the syllable-forming vowels, i and u became polyphone syllabic signs for i (= consonant y) and u (= w or v) with attached a, e, i, o, and u (𐤉𐤀 = ya, ye, etc.; 𐤅𐤀 = wa, we, etc.) and also signs for i and u alone. The uniformity of the system was thus also here preserved.

Alongside the sign 𐠊 for syllable-forming i there was already in Cypriote a syllabic sign for ia : 𐠀 𐠁. This seems to have been entirely suppressed by the Canaanites through the 𐠌 (𐤆) having been

changed into a polyphone syllabic sign, as explained above. The suppression of ia seems to have been the easier as the syllabic signs for ie, ii, io, and iu were entirely or nearly absent.

But there were in Cypriote alongside the sign for syllable-forming u also the syllabic signs for ua, uë, ui, and uo. These also are not represented in the Canaanite alphabets known to us; they have been suppressed by the polyphone syllabic sign 𐤅, which was changed from the Cypriote 𐠅. I surmise, however, that this disappearance took place gradually; that the original Canaanite alphabet possessed a sign related to the Cypriote uë which survived for a long time in private writing, although it is completely absent from inscriptions.

In the Zeitschrift der Deutschen Morgenlaendischen Gesellschaft, Vol. LVIII, p. 461 f., I have shown that the South Semitic sign for u, 𐩣, as regards its form, absolutely can not be derived from the Canaanite 𐤅, but that it is easily explained from the Greek digamma-sign 𐌅, Latin F. Nor can the Greek digamma, Latin F, be discerned in the Canaanite alphabet. I closed the discussion with the words: "Thus the agreement of the Greek digamma with the South Semitic wau points to the existence of some sign for w in the oldest time in Canaan, but which did not come to us from Canaan itself." I recognize in the Cypriote syllabic sign for uë the missing Canaanite sign. This looks like, 𐤊, 𐤋, 𐤊. Whether this sign was already simplified by the Canaanites to 𐤊, 𐤋, 𐤊, or by the Greeks, can not be known; for the South Semitic 𐩣 can also be easily explained from the Cypriote form of the sign.

I thus assume that there were once in Canaan two signs for u (w): 𐤅 (from Cypriote 𐠅) and 𐤊, 𐤊, or something similar. Both signs seem to have been considered in Canaan as mere variants and had but one place in the firmly established succession of letters in the alphabet. So also they could have had but one sound value in Canaan. The Greeks, however, adopted the two signs with separate sound values, one as digamma, the other as upsilon. This obviated the treating of both signs as mere variants; each obtained its own place. Digamma remained in the sixth place of the Greek alphabet, while upsilon was placed toward the end. There was evidently a hesitancy to disturb the traditional numerical values of the letters, corresponding to their firmly established order of succession at the beginning of the alphabet where the frequently used small numbers were ranged. The two closely related signs must therefore be separated.

I am inclined to consider it as a mere accident that the Greeks chose 𐌖 as a vowel and digamma as a consonant, and do not think that the original Cypriote values of the corresponding signs played any part in this choice. It is also evidently accidental that digamma sooner or later disappeared from both the Canaanite and Greek alphabets (but not from the South Semitic alphabet).

With the discussion of the digamma, which originated from the Cypriote syllabic sign uë, we leave the Cypriote vowel signs and come now to the signs for open syllables with initial consonant.

I shall first discuss the three "emphatic" consonants 𐠎, 𐠖, and 𐠘. The characteristic peculiarity of their enunciation is that they are followed by a vowel of the sound-color of u and o. At first sight the striking resemblance between those Canaanite signs and the Cypriote syllabic signs for tu, su, and ku might be considered merely a deceptive coincidence, but this idea is considerably weakened when it is observed that the Canaanites merely chose the Cypriote syllabic signs with inherent u for representing those three consonants which, as it were, were predisposed for u.

The Cypriote syllabic sign for tu appears as 𐠵, 𐠶, 𐠷, 𐠸, and 𐠹. From this sign originated the Canaanite 𐠎 by drawing together the external lines into a circle, while the cross inside the Canaanite sign represents the interior strokes T of the Cypriote prototype.

The Cypriote syllabic sign for su looks like 𐠳 and 𐠴. The pen was thus given four strokes. I do not think it requires much imagination to recognize the Cypriote prototype in the Canaanite 𐠖; the long bar to the left is the same in each. The triple-toothed line to the right is a cursive contraction of the disconnected short lines of the Cypriote sign.

The Cypriote sign for ku looks like 𐠬, more rarely like 𐠫. In this I see the prototype of the Canaanite 𐠘. Already in the less frequent Cypriote form there is a beginning made toward rounding up the confusion of points and rays; in the Canaanite 𐠘 they were fully contracted into a circle with a slight depression below, which is easily explained from the form of the Cypriote prototype. Here also a remarkable coincidence must be noticed. When the Canaanite 𐠘 migrated to the Greeks as *κόππα* (koppa) it obtained in most cases the value of a *κ* before o and u. I assume that this is due to the emphatic quality of the Canaanite sound discussed above, and that it is not a relic of the Cypriote sign which is its basis. Still less can this be the case with the Latin Q which originated from the 𐠘 and which in combination can be used as ku—just as the Cypriote 𐠬.

In the three signs just discussed we have found a definite reason why the Canaanites selected the Cypriote syllables terminating in u. Otherwise it might have been expected that they would have preferred those terminating in e; for the syllabic signs in e occur most frequently in Cypriote as mere consonants. Not only can they, according to fixed rules, have the value of mere consonants in the middle of a word like the other syllabic signs, but they are admissible at the beginning of a word only as consonants. Thus only 𐠊𐠎𐠏𐠐𐠑𐠒, i. e., e-ta-li-o-ne = *Ἠδάλιον* (Edalion), and 𐠓𐠔𐠕𐠖𐠗𐠘𐠙, i. e., pa-si-le-u-se = *βασιλεύς* (basileus) are possible. As the Canaanites simplified the syllabic writing known to them so as to

retain but one sign for all the syllables attached to a consonant and for this consonant itself, it seems but natural that they should have preferred those syllabic signs which were least fixed and most indifferent, such as those terminating in e. Thus we recognized above in the Cypriote syllabic sign uë the prototype of the lost Canaanite digamma.

And it seems indeed as if the Canaanites had preferred the Cypriote syllabic signs in e. I shall quote for the present the Canaanite 𐤄, the angles of which are not everywhere as pointed as in the Moabite Stone. In Cypriote the sign for ne is 𐠎. Discarding the two short strokes on either side, there remains only the Canaanite sign.

The Canaanite letter 𐤌 I would declare as a cursive abbreviation of the Cypriote syllabic sign for me. Its usual form is 𐠍, 𐠍; but there also occur forms like 𐤌 and 𐤌. It seems to me that from these, especially from the latter forms, the Canaanite sign could have easily originated. The insertion in the middle below was combined with the ray to the right above to one long bar to which the two left rays were cursively attached and straightened. The ray to the right below vanished. Something like 𐤌, 𐤌.

I must confess, however, that I do not here feel quite on solid ground, and the wealth of Cypriote signs that offer themselves for selection is disquieting. The Cypriote syllabic sign for mi is 𐠊, sometimes also 𐠊, 𐠊 and 𐠊. I do not think that the Canaanite sign 𐤌 originated from it; but the possibility can not be absolutely denied.

Likewise the slender Canaanite sign 𐤆 might have originated from the Cypriote syllabic sign for le, i. e., 𐠈. Occasional forms like 𐠈 and 𐠈 are more similar to the Canaanite sign. But here also 𐠈, li, which might also be considered as the prototype of Canaanite 𐤆, is disturbing.

As for Canaanite 𐤓 (r), the Cypriote syllabic sign for re, 𐠗 and 𐠗, hardly comes into consideration, but the Canaanite sign 𐤓 could easily have originated from 𐠗, 𐠗, ra, as well as from 𐠗, ro. The fact that the letter is named ro can hardly be adduced in favor of its derivation from 𐠗, ro.

As the Cypriote writing unfortunately does not distinguish between tenuis, media, and aspirata, the idea suggests itself that the Canaanites availed themselves of the vocalic variety of these syllabic signs in order to more precisely distinguish the character of their consonants. We have already seen that they selected the syllabic signs tu, su, and ku in order to obtain a definite designation for the specifically Semitic "emphatic" consonants. We have also seen that the choice of the syllabic ending in u was not merely a conventional matter, but had its origin in the sound-color. This origin can, however, hardly be discerned elsewhere.

I would again suggest that the Cypriote sign for pe (p^he, be), 𐠏, 𐠏, 𐠏 and similar ones might be the prototype of the Canaanite

(p). It must be admitted, however, that the forms are not sufficiently characteristic to afford basis for proof, and the correspondence of the name of the Canaanite sign, *pe*, with the Cypriote sound value is probably merely a coincidence. Still, I would even go further and see in the Cypriote syllabic sign for po the prototype of the Canaanite (b). The syllabic sign looks like , , also , , and similar ones. I believe the external resemblance between the two letters is not small.

The syllabic sign for ke (k^he, ge) in Cypriote is . Occasionally the upper angle is somewhat obtuse, and the two lower strokes are sometimes combined, as in , . The assumption seems to me self-evident that we have here the prototype of the Canaanite . And as the syllabic sign for ko is in Cypriote , , and , it is again not difficult to see in it the origin of the Canaanite sign , (). It seems as if the Canaanites derived from the same syllabic sign (k^he, χe) also the two gutturals and , although they had at their disposal the syllabic signs , ka, and , ki. The resemblance of these forms speaks clearly in favor of the assumption that and are merely different developments of the Cypriote , while in there was added on the left side a differentiating bar.

But the Cypriote syllabic signs , ta, , te, , ti, and , to, seem to have no similarity with the Canaanite (t) and (d). On the prevailing analogy it was to be expected that (te) would have developed into X, (to) into . The possibility of this development can not be denied, especially since the three strokes of the can easily be reconstructed into .

Cypriote writing has but one surd sibilant, while the Canaanite writing has three. We have already recognized above the origin of the Canaanite in the Cypriote syllabic sign for su. The Cypriote signs for se and si seem to have supplied the Canaanite and .

Cypriote se looks like , and from it originated Canaanite . The sign was formed in Canaanite by starting to the left above, in one stroke, neglecting the vertical left bar. Later there arose in Canaanite signs some forms more closely resembling the Cypriote, but which can not be directly connected with it, such as and similar ones. Here the vertical bar to the left arose from a cursive need. The usual form of Cypriote si is, , , sometimes , , , also . I believe the way to Canaanite and Greek is not very far from it. It may be worth mentioning as a coincidence that the picture of the Cypriote syllabic sign involuntarily reminds one of the Canaanite name of the letter samek, "support."

I thus claim for about half of the twenty-two signs of the Canaanite alphabet a certain knowledge of their origin. And this certainly lends some weight to the consideration of the other resemblances and surmises that otherwise would have to be dismissed without further reflection as coincidents and fantasies.

THREE ARAMAIC PAPYRI FROM ELEPHANTINE, EGYPT.[a]

By Prof. EDUARD SACHAU.

The very ancient records here for the first time made known to the learned world are noteworthy in many respects. They are remarkable for their language and for their contents. They are especially valuable because of their relation to the latest historical books of the Old Testament, the Chronicles and the books of Ezra and Nehemiah. They also throw light on the history of the Jews during the little known period between the activity of Nehemiah and the appearance of Alexander the Great. In language they are essentially identical with the Aramaic chapters in the books of Ezra and Daniel, and in phraseology they present many points of contact with the official records in the book of Ezra. They relate to the rebuilding of a destroyed temple, just as the book of Ezra relates to the rebuilding of the temple and the walls of Jerusalem.

It was the achievement and good fortune of Dr. Otto Rubensohn to have found these papyri during the recent excavations on Elephantine, an island in the Nile opposite Assuan, a city on the eastern bank of the river, on the border of Egypt and Nubia. Among the results of his excavations, there reached the Royal Museum of Berlin, besides larger and smaller pieces and fragments of papyri, several still unopened scrolls. When these were unrolled by Mr. Ibscher, the curator of the papyri at the museum, they were found to be in part Aramaic, among them the one designated here as No 1. Doctor Rubensohn describes the discovery as follows:

> The mass of ruins (*Kom*) situated on the south point of the island of Elephantine, and representing the ancient city of the same name, is on its northern half covered with a dense maze of walls of unburnt bricks, the remains of private dwellings of various periods of antiquity. The entire northern half of

[a] Translated and abstracted, by permission, from "Drei Aramaeische Papyrusurkunden aus Elephantine" by Eduard Sachau in the Abhandlungen der koeniglichen preussischen Akademie der Wissenschaften for the year 1907.

the *Kom* has been thoroughly devastated during the last decades by the sebah diggers or the fellahin, in search of ammoniacal earth, so that at present the undisturbed part of the *Kom* along its west, particularly the southwest, forms a steep precipice toward those parts of the ancient city dug over by the fellahin and thus brought down to a low level.

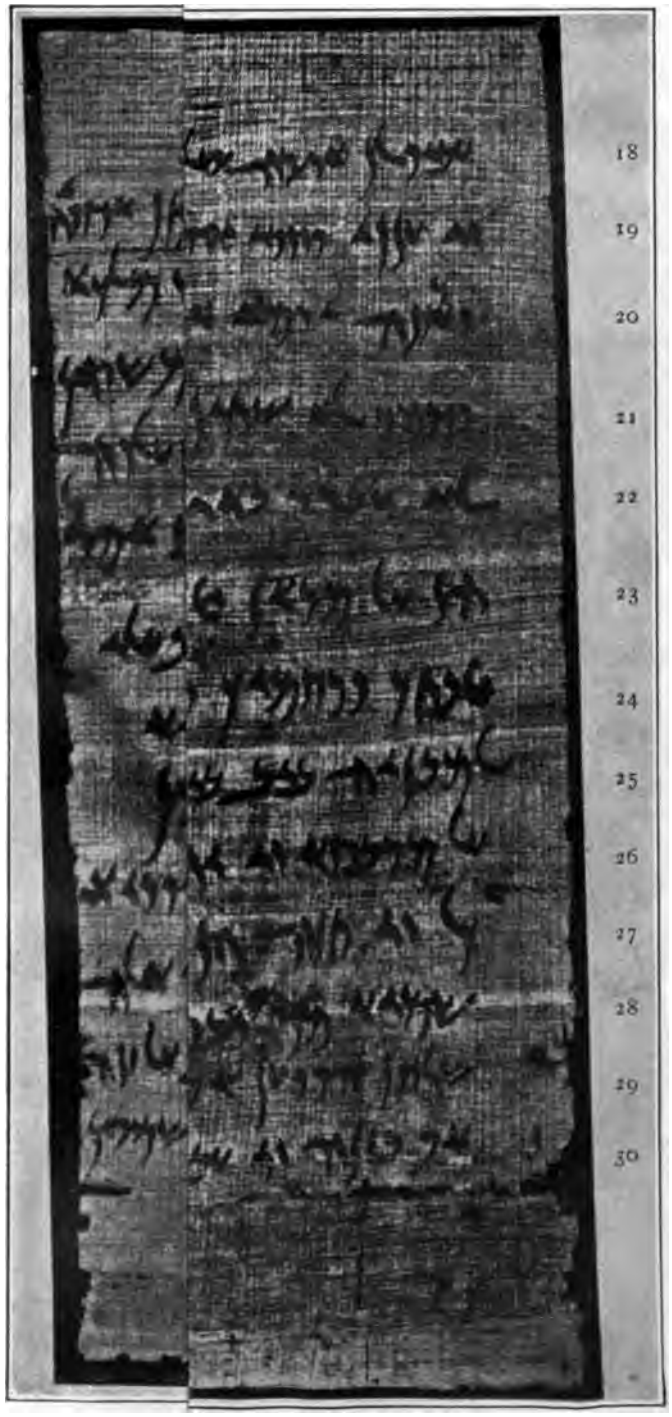
The Aramaic papyri came to light in two rooms in two different but not widely separated house groups, not very distant from the present western edge of the *Kom*. By far the larger part of the finds was in the southern room; from the northern only a few fragments were obtained. The building containing the Aramaic finds was in a very poor state of preservation, like almost all the other brick structures of Elephantine. Besides this, the southern house here described had evidently been rebuilt at various periods, and the remnants of walls of a construction very similar to the first made its survey extremely difficult. It was therefore impossible to determine accurately the ground plan of the house. The destruction is only to a limited degree the result of time, but is chiefly due to the activity of the sebah diggers, traces of whose work were plainly visible, indicating comparatively recent operations. The spot where the Aramaic papyri purchased by Mr. Mond were found was pointed out to me two years ago by the dealer who sold them, and in our first campaign in February, 1906, we excavated from this point south, unearthing Greek papyri. In the present campaign we worked northwards and soon came upon the Aramaic documents here described. There can be no doubt, therefore, but that those in the museum at Cairo came from this very room. The Cairo papyri, according to the statements of the dealers, were in a pot, while the Greek papyri discovered in our first excavations were deposited in a similar manner in two pots. These new Aramaic documents, however, were found in the débris near the eastern and southern walls of the room, scarcely half a meter below the present surface. The first two pieces were in the rubbish outside of the room to the west, where they had evidently been transferred by earlier unauthorized diggers. * * *

The finds of Doctor Rubensohn come from the archives of such Jewish colony as must have lived at Elephantine. They have a close relation to the Aramaic papyri discovered at Assuan, which have been edited by A. H. Sayce with the assistance of A. E. Cowley (London, 1906), and which in all probability, though they came to light at Assuan, were originally found at Elephantine and formed part of the papyrus treasure, the final discovery of which was reserved for Doctor Rubensohn. The documents edited at Oxford belong to the same period as those now at Berlin; they originated under the same circumstances, were composed in part by the same persons, and the same names appear in them as in these later finds.

DOCUMENT I.

Containing a petition of Jedoniah and his fellow-priests of the Jewish temple of Elephantine addressed to Bagohi, the Persian governor of Jerusalem, asking for the restoration of their temple, which was destroyed through the machinations of the Egyptian priests of the god Chûm (or Hnub). Written in 408–407 B. C. (Pls. I and II.)

PLATE I.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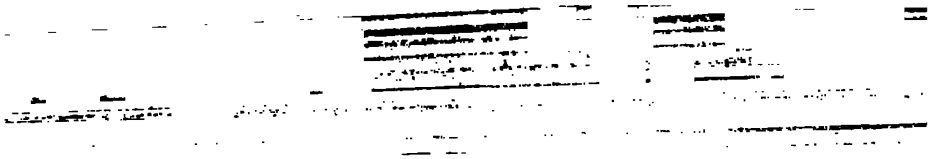


TRANSLATION.

1. To our Lord Bagohi, governor of Judea, thy servants, Jedoniah and his companions, the priests in the fortress Yeb; Greeting:
2. May our Lord, the God of Heaven, grant thee peace abundantly at all times, and give thee favor before King Darius and
3. the sons of the royal house a thousandfold more than now, and give thee long life! May joy and health be thine at all times!
4. Now thy servants, Jedoniah and his companions, speak thus: In the month of Tammuz (July-August), in the 14th year of King Darius, when Arsam
5. departed and went to the King, the priests of the god Hnub in the fortress Yeb entered a conspiracy with Waidrang, who was the governor here, as follows:
6. "The temple of the God Jahu (Yahu) in the fortress Yeb shall be removed." Thereupon Waidrang sent
7. letters to his son Nephayan, who was commander of the fortress Syene, saying: "The temple in the fortress
8. Yeb shall be destroyed." Thereupon Nephayan brought Egyptians together with other soldiers. They came to the fortress Yeb with their * * *
9. They entered into that temple and destroyed it to the ground, and broke to pieces the pillars of stone that were there.
10. They destroyed also the five gates, built of hewn stone, which were in the temple, and their tops (?) * * * and bronze hinges
11. in marble slabs (?) and the roof, made wholly of cedar wood together with the stucco (?) of the wall (?) and other things that were there,
12. all this they burnt with fire. And the bowls of gold and silver and whatever was in the temple they took
13. and appropriated to themselves. And since (already in) the days of the Kings of Egypt had our fathers built this temple in the fortress Yeb. And when Cambyses entered Egypt
14. he found this temple built, and while the temples of the gods of Egypt were then all overthrown, no one injured anything in this temple.
15. And since they [Waidrang and the priests of Hnub] have done this, we with our wives and children have put on sackcloth and fasted and prayed to Jahu, the Lord of Heaven
16. who gave us cognizance of Waidrang [*i. e.*, punished him]. The chain was removed from his feet, and all the possessions which he acquired perished and all the men
17. who wished ill to his temple were slain, and we saw it ourselves to our satisfaction. And before this, at the time when this evil was done us,
18. have we sent a letter to our Lord (Bagohi) and to Jehohanan (John), the High priest, and his companions, the priests in Jerusalem, and his brother Ostan,
19. that is, Anani [Hannani] and the nobles of the Jews, but they sent us no answer. Also since the Tammuz day of the 14th year of King Darius
20. to this day we wear sackcloth and are fasting. Our wives have become like widows. We have not anointed ourselves with oil
21. nor drank wine. Neither from that day to this day of the 17th year of King Darius have meal-offerings, frankincense or burnt-offerings
22. been offered in this temple. Now thy servants, Jedoniah, and his companions, and the Jews, all the citizens of Yeb, speak thus:
23. If it seem good to our lord, mayest thou think about this temple to rebuild it, since we are not permitted to build it, and look upon the recipients

24. of thy benefits and of thy mercy here in Egypt. May a letter be sent from thee to them concerning the temple of Jahu
25. that it be built again in the fortress Yeb as it was built in former times. And we will offer meat-offerings and frankincense and burnt-offerings
26. upon the altar of the God Jahu in thy name. And we will pray for thee at all times, we and our wives and our children and all the Jews
27. who are here when this will be done, until the temple is built. And thou shalt have a portion before Jahu, the God
28. of Heaven, from every one who offers to him burnt-offerings and sacrifices in value equal to a silver shekel for * * * And concerning the gold
29. we have sent message and made known. We have also all of us written concerning these matters in a letter in our name to Delaiah and Shelemiah, the sons of Sanballat, the governor of Samaria.
30. Arsam also has no knowledge of all that has been done to us. The 20th of Marheshwan (October-November), in the 17th year of King Darius.

It is well known that Elephantine, whose old Egyptian name was Abu, Ibu, Iab, or Ib, which in Greek and Aramaic become Ieb or Yeb, was, under Persian and Roman dominion, a fortress with a garrison guarding the frontiers against Nubia. It is also known from classical and Egyptological writings that the ram-headed Chnemu or Hnub was worshipped in Elephantine together with other divinities. (Compare Strabo, C 817.)

Bagohi, to whom the letter is addressed (line 1), and Jehohanan, the high priest at Jerusalem (line 18), are undoubtedly identical with Bagoas or Bagoses and Ioannes mentioned in Josephus's Antiquities, XI, 7, where it is related that while Bagoas (Bagoses) was Persian governor in Jerusalem the High Priest Ioannes slew in the temple his brother Jesus, who contested the dignity of the high priesthood. Bagoas thereupon invaded the temple and imposed upon the Jews a fine of 50 drachms for every lamb that there was to offer in the temple. The High Priest Jehohanan is also mentioned n Nehemiah, XII, 22. Jedoniah, who appears as head of the Jewish community in Elephantine, occurs also in the Aramaic papyrus of Assuan. In Jadon, Nehemiah, III, 7, may be seen an abbreviation of this name. Sanballat, who is named as governor of Samaria (line 29), is the well-known adversary of Nehemiah. (Compare Nehemiah, II, 10, 19; III, 33; IV, 1; VI, 1.) His sons are not mentioned in the Old Testament; but the names they bear, Delaiah and Shelemiah, often occur in the time of and in connection with Sanballat. (Compare Nehemiah, VI, 10–12; XIII, 13; I Chronicles, III, 24; XXIV, 18.)

But that the community of Elephantine should turn for assistance to the sons of one who had been the bitterest foe of Nehemiah and of the restoration of the Jewish nation and its cult in Palestine seems rather strange. Can it be that the Jews of Elephantine were in entire ignorance of Nehemiah and his great national work? Or, since Nehemiah's return to Babylon (about 433 B. C.) had his con-

flict with Sanballat become so much a thing of the past that the community believed it could ignore these things without fear of giving offense? Or, were the Jews of Elephantine derived not from Judah and Benjamin but from various parts of the old kingdoms of Judah and Israel (they might have come to Egypt already before the overthrow of both of these kingdoms), so that they could consider themselves as being not direct parties to the political and religious differences between Jerusalem and Samaria? However this may be, it appears certain, that they did not act in the spirit of Nehemiah when they asked the sons of his hereditary enemy for help.

Arsam (lines 4 and 30) is possibly identical with Arsanes of the Greek historian Ktesias, who was governor of Egypt when Darius II, Nothus, 424–405 B. C. (the king referred to in lines 4, 21, and 30), acceded to the throne. His temporary absence from Egypt was taken advantage of by the priests of Chnemu, who bribed his subordinates, and with their assistance, under the leadership of Waidrang, a Persian magistrate of Elephantine, destroyed the temple of the Jewish community. According to lines 16 and 17 a reaction soon set in; the enemies of the Jews were deprived of the fruits of their plunder and were all killed before their eyes. As to the manner of this reaction and by whom it was brought about, nothing is said in the document. It may be assumed that Arsam had meanwhile returned to Egypt. But, though the evil doers had been punished, the effects of their evil deeds were not remedied. The house of God still lay in ruins and the congregation was not allowed to rebuild it. Who these new adversaries were is not recorded. Hence the petition to Bagoas.

Document II is a duplicate of Document I, with only slight variations.

Document III shows, if I am not greatly mistaken, that the ardent wish of the Jewish community of Elephantine, the permission to rebuild its destroyed temple, was granted, for this short but complete papyrus can be interpreted in this sense without stretching the imagination. This document is not the written answer of any of the three addresses mentioned in Document I, but in my opinion it is a note preserved in the archives of this community of Elephantine concerning the oral answer which Bagoas, the Persian governor of Judea, and Delaiah, the son of Sanballat, the governor of Samaria, gave Jedoniah, the bearer and writer of the petition.

TRANSLATION.

1. Account of that which Bagohi and Delaiah said to me. The account is as follows:
2. "Thou shalt speak in Egypt
3. before Arsames concerning the altar house of the God
4. of Heaven which had been built in the fortress Yeb
5. before our time, before Cambyses.

6. Which Waidrang, that * * * has destroyed
7. in the 14th year of King Darius.
8. To be rebuilt in its place, as it was before
9. and meal-offerings and frankincense shall be offered upon
10. that altar likewise as before
11. was used to be done."

To sum up the facts to be derived from these documents:

There was in Elephantine in the fifth century B. C. a Jewish community which possessed a spacious, well-built temple with five gates and a cedar roof. The builders of the temple had been rich enough to have cedars transported from the far Lebanon forests to the border of Nubia, and their descendants were rich enough to have sacrificial bowls of gold and silver.

The temple had already existed for a long time when Document I was written in 408–407 B. C. Cambyses, when he entered Egypt in 525, found it there, and while he destroyed the temples of the gods of Egypt he, the son of the great prince who allowed the Jews living in Babylonian captivity to return to their home, did not inflict any injury to the temple of the Jewish community in Elephantine. When was this temple built? When was the Jewish community in Elephantine settled? After the destruction of Jerusalem by the Babylonians in 588? After the destruction of Samaria by the Assyrians in 723? The documents and fragments of documents discovered at Elephantine, instructive as they are concerning many other things, give no information on these points.

In this temple they offered to the God Jahu, the Lord of Heaven, their prayers, their burnt-offerings, meal-offerings, and frankincense. They worshipped him with undivided loyalty. There is here no trace of their having turned away in any manner toward the gods of Egypt. When their temple was destroyed they mourned in sackcloth and with fasting; they had no consecrated place where they could serve their God, and in touching words they pronounced their gratitude to the man who could perhaps procure them the possibility of rebuilding their temple, promising, with their wives and children, to pray to their God for him, a Zoroastrian.

The Jews enjoyed the protection of Darius, Xerxes, and Artaxerxes. Under their régime they had led a peaceful and in every respect satisfactory existence, and it was only when Arsames, the Persian governor, left the country to go to the court of the King that a conspiracy of Egyptian priests and Persian subordinate officials succeeded in destroying the sanctuary of the Jewish community. But the reaction which soon followed and the punishment of the evil doers seems again to have been the work of the Persian Government.

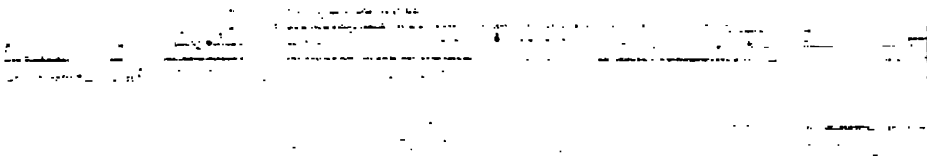
Thus these documents show anew that the policy of the Achemenides was favorable to the Jews. Cyrus gave them permission to

return. Under the Cambyses the temples of Egypt were destroyed, but the Jewish temple in Elephantine was spared. Under Persian rule in Egypt the Jewish community was able there to erect and maintain a magnificent house of God. When the Persian governor left the country, the enemies of the Jews, Egyptian priests and their allies, gained the upper hand and destroyed and pillaged the house of God. And again it was a Persian, the governor of Judea, to whom they turned with a petition for redress, after the high priest of their own nation and religion in Jerusalem, Jehohanan, had ignored their petition. (See Document I, line 19.)

When Jeremiah prophesied to his countrymen in Egypt of their extermination through sword, famine, and pestilence (Jeremiah XLIV, 11 ff.), he intimated in one passage at least that they longed to return to the fatherland. (Jeremiah XLIV, 14: "that they should return into the land of Judah, to the which they have a desire to return to dwell there".) Such a longing can not be discerned in these papyrus documents, but they show how the Jews of Elephantine, when trouble befell them, turned their eyes in search of help to Palestine, to the high priest in Jerusalem, and to the governors of Israel and Judah appointed by the Persian Government. They must, therefore, have been at that time without influential protectors in Egypt itself.

The language of the documents is pure Aramaic, as pure as only such model Aramaic writers as Aphraates, Ephraem, and Narses write. The date of these documents is important for the early history of the Arameans, which, notwithstanding all researches, is still obscure. These documents are valuable for their dialect, which in this early period was closely akin to Hebrew, and also for the light they throw on the history of Hebrew. My impression is that Hebrew for the Jews in Elephantine in the fifth pre-Christian century was at most only the language of the cultus and sacred writings. That they wrote their business documents in Aramaic may have been out of consideration for the government authorities before whom the affairs had eventually to be transacted. But if they also composed their narratives and poetry in Aramaic and not in Hebrew, as these papyri indicate, the conclusion would be that Aramaic was certainly the vernacular among them, the language of old and young, of man, woman, and child.

The excavations in Elephantine have enriched the Old Testament with a new and significant chapter. What will their continuation bring to light? As to the fact that they must be continued, there can be no question among the friends of the Bible and of antiquity, and it is to be hoped that there will be no lack of funds in the present day when all are so enthusiastic on the subject of excavation in Bible lands.



THE PROBLEM OF COLOR VISION.[a]

By JOHN M. DANE.

The problem of color vision is one of the most intricate which the biologist is asked to solve. The following paragraphs are intended to indicate the several methods which are being employed for its solution, together with some of the results thus far obtained. The anatomy of color vision will be considered first; then in turn its physiology and its development; and finally, the abnormal conditions of color blindness, together with the theories of normal vision to which they have given rise.

Anatomy.—The mechanism of color vision is lodged in the rod and the cone cells. A ray of light, after passing through the lens of the eye and its vitreous body, penetrates several layers if the retina, thus arriving at the proximal ends of the elongated rod and cone cells. These sells are arranged in a single row. The light traverses the length of the cells to their distal ends which it stimulates. The rod and cone cells project against a single layer of heavily pigmented cells, the *stratum pigmenti retinæ.* (Fig. 1, S. P.) These have non-retractile processes which are found between the rods and the cones. The pigment fuscin, in the form of elongated or crystalloid granules, migrates into these processes when the eye is illuminated; in the dark it is withdrawn into the cell body.

Every rod cell consists of a rod, a rod fiber, and a nucleus, arranged as shown in fig. 1, A. A rod, which is from 40 to 50 μ long and 1.5 to 2 μ in diameter, consists of a doubly refractive, lustrous *outer segment*, and a singly refractive, finely granular *inner segment.* In serum or dilute osmic acid the outer segment breaks into a series of regular transverse disks which are believed to indicate a stratified structure in the living rods. Visual purple is a pigment which occurs only in the outer segments of the rods. It bleaches rapidly in the light, but (unless the pigmented stratum has been removed experimentally) it is soon restored in the dark. Light thus appears to incite chemical processes in the outer segments of the rods. The inner segments are sometimes described as having a longitudinally fibrillar structure in

[a] Reprinted, by permission, from the American Naturalist, Vol. XLI 486, June, 1907.

their outer portions. The opposite ends pass rather abruptly into the very slender rod fibers. Each fiber somewhere in its course expands to inclose the nucleus, and finally terminates in a pyriform enlargement. The nucleus in preserved specimens may have its chromatin arranged in a few broad transverse bands.

Every cone cell consists of a cone, a cone fiber, and a nucleus. The cones like the rods are divisible into outer and inner segments. The outer segment is usually shorter than that of the rod (12 μ) and tapers somewhat to its rounded extremity. It never contains visual purple, but otherwise, as for example in breaking into transverse disks, it resembles the outer segment of the rod. The inner cone segment bulges like the body of a flask. It is divided into an outer, longitudinally fibrillar *ellipsoid* portion, and an inner contractile *myoid* portion. The noncontractile ellipsoid is said to become strongly eosinophilic in the dark. Because of the myoid substance the cones, unlike the rods, may alter their length. The contractility is said to be less in man than in the pig, and less in the latter than in some amphibia and fishes where the myoid segment is reported to shorten from 50 μ to 5 μ. The nuclei are found in a mass of protoplasm near the base of the cone; beyond the nucleus the protoplasm forms a cone fiber which is thicker than that of a rod and which ends in a branched and expanded base.

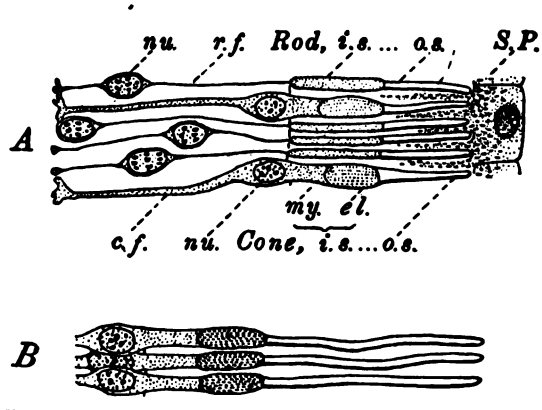


FIG. 1.—A, diagram of human rod cells and cone cells from the equatorial part of the retina. *B*, cone cells from the fovea, drawn on the same scale.

The stimuli received by the outer segments of the rods and cones are transmitted through their fibers to the nerve cells of the retina, and thence to the brain. A single retinal nerve cell receives the stimuli from several rods and cones.

Since rods and cones are believed to have different relations to the perception of color, their distribution in man and other animals should be significant. In the peripheral portion of the human retina rods are in excess, so that in sections three or four rods appear between every two cones. Near the depression, or *fovea*, where vision is most acute, rods and cones are equally abundant, and in the fovea itself only cones are found. These cones, however, are strikingly

rod-like in form, and greatly exceed the rods in length. (Fig. 1, B.) Slender cones are also found in the thickened *area centralis* which in many mammals replaces the human fovea.

In the ape, horse, pig, cow, sheep, and dog the rods and cones are similar to those of man. In rodents which avoid the light the cones are " very small and hard to detect since their inner segments scarcely differ from those of the rods, from which they may be distinguished by their much shorter outer segment. M. Schultze at first questioned the existence of cones in the mouse, guinea pig, mole, hedgehog, and bat. The cat undoubtedly has cones, but they are small, slender, and, except in the *area*, infrequent." [a] Birds have a single or double fovea, like that of man. Cones are small but very numerous, and in their inner segments they often contain a drop of oily substance, either colorless or various shades of yellow, green, or red. Presumably these drops, which are absent from the rods and some of the cones, exert an important influence upon color perception. In owls the bright colored drops are lacking and the cones are said to be fewer. Some reptiles have foveæ; two kinds of visual cells are reported, neither of which resembles the mammalian rods. M. Schultze believed that reptiles have only cones. In fishes and amphibia, both rods and cones occur; in some sharks, rays, and eels, however, the cones so resemble rods that they may be overlooked. Whether or not deep-sea fishes are without cones is apparently unknown. In the various groups of animals the rods and the cones each present modifications of structure, with which as yet physiological observations have not been correlated.

PHYSIOLOGY.

The physiology of color vision is the study of the functions of the rod and the cone cells. In passing from a bright to a very dim illumination one experiences a momentary blindness; after becoming accustomed to the darkness, a modified form of vision is regained. In this *twilight vision* the fovea is far less sensitive to light than the more peripheral parts of the retina. Moreover all objects appear in shades of gray. The spectrum is bright but colorless, and its brightest part has shifted from the yellow portion toward the blue. Von Kries has explained these facts by assuming that the cones are the agents of day vision, and the rods of twilight vision.[b] Cones, exclusively, occur in the fovea where day vision is most acute; and rods predominate where twilight vision is at its best. The fluctua-

[a] The quotation, and much of this account of the retina, is from Von Ebner's résumé in Koelliker's Handbuch der Gewebelehre, 1902, vol. 3, pp. 818–832.

[b] Von Kries presents this Duplizitätstheorie in Nagel's Handbuch der Physiologie, 1904, vol. 3, pp. 168–193.

tions in the visual purple of the rods show that they respond to the varying intensities of dim light, and this purple is known to disintegrate most rapidly in green light which appears brightest in twilight vision. Whether or not the bleached rods are active in day vision has not been determined.

It is probable that all cones do not respond to color stimuli. In the peripheral portion of the retina there is a partially color-blind region where red and green can not be distinguished from one another, and the outermost portion of the retina is always totally color blind. Since cones occur in these areas they also must be color blind. From these considerations it is reasonably assumed that, in human vision, the ability to perceive colors depends upon the differentiation of certain of the cones.

Since at the present time the nature of vision can not be determined by the microscopic examination of the retina, and since a very efficient vision may exist without color perception, it may fairly be questioned whether the lower animals are capable of color vision. The biological importance of this problem is very great, since prevalent theories of the development of the colors of flowers, and the bright plumage of male birds, assume a color perception in insects and female birds essentially like that in man. To learn what a bee actually sees has been thought impossible since it requires that one should possess the nervous system of an insect and still remain a man.

There is a large literature dealing with the distinctions which the lower animals make between various colors, but the factor of intensity or brightness has seldom been satisfactorily eliminated. The trout fisherman is confident that one fish, at least, discriminates colors with precision. Careful experiments with the chub, by feeding it from colored forceps and taking certain precautions to eliminate brightness, indicate that the chub distinguishes red from green and from blue.[a]

Nagel, who is convinced that the phenomena of mimicry and warning colors demand color vision in animals, experimented with the dog. After taking precautions to eliminate brightness, he proved that the dog perceived the difference between red and blue, blue and green, and red and green.[b]

Kinnaman tested the monkey, *Macacus rhesus*. Its food was placed in one of six receptacles, precisely alike except that each was of a different color. When the monkey had learned to choose correctly

[a] Washburn, M. F., and Bentley, I. M. The establishment of an association involving color discrimination in the creek chub. Journ. of Comp. Neur., 1906, vol. 16, pp. 113-125.

[b] Himstedt, F., and Nagel, W. Versuche über die Reizwirkung verschiedener Strahlarten auf Menschen und Tieraugen; Festschrift der Albert-Ludwigs-Universität in Freiburg, 1902.

the food-containing glass, a different color was selected. Thus the monkey learned to proceed at once to the receptacle with food, whether it was blue, yellow, red, or green. It was tested also with a black and light gray glass. Having learned that the food was in the former, successively darker grays were substituted for the empty one. The percentage of wrong choices increased and it was found that grays were confused which the human eye can distinguish with perfect ease and certainty. Kinnaman concludes that "there can be no doubt that monkeys perceive colors." Two colors of equal brightness are distinguished better than two grays of equal brightness; and though the brightnesses are the same, colors may be distinguished from grays.[a]

In the dancing mouse, however, the cones of which are at least very rod-like, Yerkes has recently found that color vision is extremely poor. There is some evidence of discrimination of red and green, and of red and blue, but none whatever of blue and green. Apparently such visual guidance as is received results from differences in brightness. The mouse discriminates blacks, grays, and whites.[b]

Because of the inherent difficulties in the investigation of color vision in the lower animals, comprehensive results have not yet been obtained, but the newer methods promise notable discoveries.

DEVELOPMENT.

Since color vision is a complex differentiation, it might be expected that in the course of development an individual should successively pass through the simpler stages by which it was acquired. Anatomically it has been shown that the retinal layers first become distinct at the center of the retinal cup, and that the differentiation of the retinal cells decreases from the center toward the periphery. In the chick it is said that the cone nuclei may be identified at an earlier stage than the rod nuclei,[c] but it is not generally recognized that one form of visual cell precedes the other.

The development of color vision has been theoretically considered by Mrs. Ladd Franklin.[d] Her theory assumes that the colorless sensations, white, gray, and black, are caused by a primitive photochemical substance called the gray substance, which is composed of numerous gray molecules.

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[a] Kinnaman, A. J. Mental life of two Macacus rhesus monkeys in captivity. Amer. Journ. of Psych., 1902, vol. 13, pp. 98–148.

[b] Yerkes, R. M. The sense of vision in the dancing mouse. Journ. of Comp. Neur., 1907, vol. 17, p. 194.

[c] Weysse, A. W., and Burgess, W. S. Histogenesis of the retina. Amer. Nat., 1906, vol. 40, pp. 611–634.

[d] Franklin, C. L. On theories of light sensation. Mind, 1893, n. s., vol. 2 pp. 473–489.

These gray molecules, which persist in their primitive state only in the rods, upon disassociation furnish us with the gray sensations. In the cones the gray molecules have undergone a development such that a certain portion only of the molecule becomes disassociated by the action of light of a given color.

The differentiation of the primitive gray molecule is supposed to have taken place in three stages. (Fig. 2.) The first stage is represented by the simple, primitive gray molecule, so constructed that it is disintegrated by light of any color, thus producing a gray or white sensation. In the second stage the molecule is more complex and contains two groupings, the disassociation of one of which gives the sensation of yellow and the disassociation of the other gives blue. The simultaneous disassociation of both gives white. This stage persists in the peripheral portion of the retina where neither green nor red can be perceived as such. In the third stage the yellow grouping is divided to form two new combinations, the disassociation of one of which produces the sensation of green and the other the sensation of red. If the red and green groupings are disassociated together the resulting sensation is yellow; whereas the simultaneous disassociation of the red, green, and blue groupings produces the white sensation.

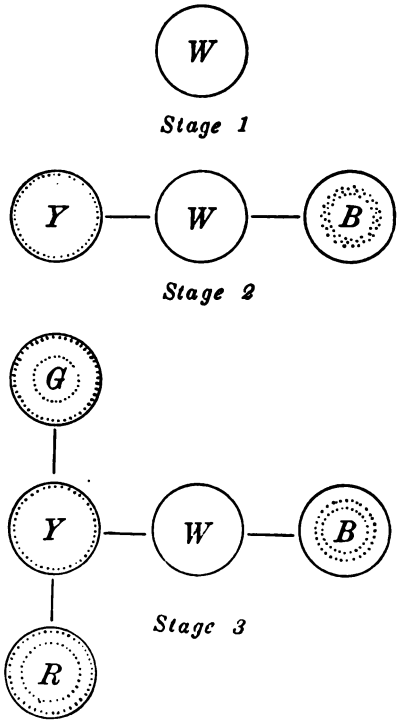


FIG. 2.—Diagram to illustrate the Franklin theory. The blue, green, and red groupings are represented by an outer, middle, and inner circle of dots, respectively. Disassociated groupings are omitted.

Schenck[a] has somewhat extended this theory by describing the development of the primitive gray molecule. Since in twilight vision the red end of the spectrum is lost, and the green-blue portion is its brightest part, he considers that the photochemical substance of the rods is attuned only to the green-blue light, which is perceived as colorless. Later this photo-chemical substance becomes sensitized in two stages, first to include the

[a] Schenck, F. Über die physiologischen Grundlagen des Farbensinns. Sitzber. d. Gesell. d. ges. Naturw. z. Marburg, 1907, Jahrg. 1906, pp. 133–164.

green-yellow, and then the yellow-red, which however are still perceived as colorless light. Thus a gray molecule like that of Mrs. Franklin's first stage is constructed. It occurs in the color blind peripheral cones. The formation of color-reacting groupings in the partly sensitized gray molecule leads, according to Schenck, to those forms of human vision in which the red end of the spectrum is shortened.

Observations upon the color perception of young children do not support these developmental theories. Holden and Bosse[a] tested two hundred children by placing before them square pieces of colored paper attached to a gray background of similar brightness. If the child made an effort to grasp the square, its color must have been perceived. It was found that the average child would react to all colors by the tenth month, the red end of the spectrum causing response a little earlier than the violet end. When ribbons of six spectral colors were placed before children of from seven to twenty-four months, red was selected first; orange or yellow second and third; and green, blue, and violet last of all. Nagel[b] showed his child of twenty-eight months each of the spectral colors in varying degrees of brightness, at the same time teaching him their names. Red and green were learned easily, but blue was acquired with greater difficulty than any other color, including violet. Green, violet, and red were preferred; black, yellow, white, gray, and blue had secondary rank. Other experiments with the color perception of children have given different results. It is clear, however, that children are not known to pass from a color blind stage, through one of yellow-blue vision, to a discrimination of all the spectral colors. No race of men now exists in which any of the colors is unknown; and the notion derived from studying the color terms and references in ancient literature, that man in historic times had a deficient color sense, is not substantiated. It may be that, as in children, the red portion of the spectrum was preferred to the blue, but even this is not established.

COLOR BLINDNESS.

All the colors which are normally perceived may be produced by combinations of the spectral red, green, and blue. Normal vision is therefore *trichromatic*. Sometimes in trichromatic vision the red end of the spectrum is shortened; in other cases a mixture of red and green, which to normal persons appears pure yellow, may seem

[a] Holden, W. A., and Bosse, K. K. The order of development of color perception and color preference in the child. Arch. of Ophth., 1900, vol. 29, pp. 261–277.

[b] Nagel, W. A. Observations on the color sense of a child. Journ. of Comp. Neur., 1906, vol. 16, pp. 217–230.

tinged with red or green. Thus there are variations in trichromatic vision. Greater abnormalities may take the form of *dichromatic* and *monochromatic* vision. The latter is a rare pathological condition in which all colors are perceived as shades of one; vision, therefore, is essentially colorless (achromatic), the images obtained being comparable with photographs. In dichromatic vision color perception is so limited that all of the shades perceived may be made by combining two of the spectral colors red, green, and blue; blindness to the third of these colors may be partial or complete. The ordinary color blindness is dichromatic. Forty men and four women per thousand are either wholly unable to perceive certain colors or can recognize them only with difficulty. This defect is usually congenital and hereditary. It may cause so little trouble as to pass undetected until the age of seventy. All attempts to overcome the color blindness by educating the color sense in various ways have failed.

Since dichromatic color blindness plays so large a part in the theories of normal vision, a portion of Doctor Pole's description of his own case is here inserted. He says,[a] "In the first place we see white and black and their intermediate gray, provided they are free from alloy with other colors, precisely as others do. (Such statements are confirmed by those who are color blind in one eye, the other being normal.) Secondly, there are two colors, namely, yellow and blue, which also if unalloyed we see, so far as can be ascertained, in the normal manner. But these two are the *only* colors of which we have any sensation. It may naturally be asked: Do we not see objects of other colors, such as roses, grass, violets, oranges, and so on? The answer is that we do see all these things, but that they do not give us the color sensation correctly belonging to them; their colors appear to us as varieties of the other color sensations which we are able to receive. Take, for example, the color red. A soldier's coat or a stick of sealing wax conveys to me a very positive sensation of color, by which I am perfectly able to identify, in a great number of instances, bodies of this hue. But when I examine more closely what I really see, I am obliged to conclude that it is simply a modification of one of my other sensations, namely, yellow. It is in fact a yellow shade with black or gray, a darkened yellow or yellow brown."

Dichromatic vision occurs in three forms, in two of which red and green are not differentiated from one another. The three forms are named *protanopia*, *deuteranopia*, and *tritanopia*, respectively. In protanopia the red end of the spectrum is shortened; that is, a portion which to the normal person is red appears black. The remainder of the red, the orange, the yellow, and the green appear as successively

[a] Pole, W. Color blindness in relation to the Homeric expressions for color. Nature, 1878, vol. 18, pp. 676–679.

lighter shades of yellow which, toward the blue, becomes gray or white. This white shades into blue, which deepens toward the violet end of the spectrum. In deuteranopia, which is the normal condition of a peripheral zone of the retina, the red of the spectrum is not shortened. Red, orange, yellow, and green appear as lighter shades of one color, called red or yellow, and shade into a white or gray band which is a little nearer the red end of the spectrum than the corresponding band of protanopia. Blue is perceived normally. Tritanopia is a rare form in which yellow and blue are not recognized. The spectrum presents red and green portions, separated by a white band in place of the yellow. A dark green is seen in place of blue and the violet end of the spectrum is shortened.

THEORIES OF COLOR VISION.

Certain features of color blindness are ingeniously explained by Hering's theory, illustrated in figure 3. It is supposed that the cones contain a photo-chemical substance which is disassociated by red rays, but which is built up by the green rays, giving rise respectively to the sensations of red and green. A second substance is broken down by yellow and built up by blue light. As shown in the figure, orange is a mixed sensation due to the simultaneous partial destruction of red-green and the yellow-blue substances. Yellowish green and greenish blue are likewise mixtures, and violet is supposed to combine the partial construction of the yellow-blue with the destruction of the red-green, the latter being indicated by the broken line. There are four pure sensations, red, yellow, green, and blue. Color blindness may be due to the absence or deficiency of the red-green substance (protanopia and deuteranopia, the two forms being varieties of a single type), or to lack of the yellow-blue substance (tritanopia). Hering further considered that there was a white-black substance, built up in darkness to give rise to the sensation of black, but destroyed in varying degree by different colored lights, thus giving white. In monochromatic vision the retina contains only this white-black substance. The curve *w* of figure 3 shows that the maximum stimulation of white is in the yellow portion of the spectrum. Without considering the difficulties concerning the white-black hypothesis, it may be questioned whether both constructive and destructive chemical processes can produce color sensations of similar nature. Mrs. Franklin considered that her theory was supported by the fact that the color sensations were all chemically destructive. Hering's theory, moreover, calls for four primary color sensations, whereas physicists recognize that only three are
Accordingly the physicist Young proposed a sim

dating that of Hering. It was advocated by Helmholtz, and is generally known as the Young-Helmholtz theory.

According to the Young-Helmholtz theory there are three photochemical substances, red, green, and blue, respectively, which are stimulated by the various rays of the spectrum as shown in figure 4. Absence of stimulation produces black, and the simultaneous disassociation of all three yields white. Protanopia is interpreted as red blindness, due to deficiency of the red perceiving substance. Deuteranopia is green blindness, and tritanopia is blue blindness. Since it would appear that the perception of white must be lost with the disappearance of one of the three elements, the theory has been variously modified. In protanopia the red and the green substances may be so altered that each responds both to red and green light (Fick),

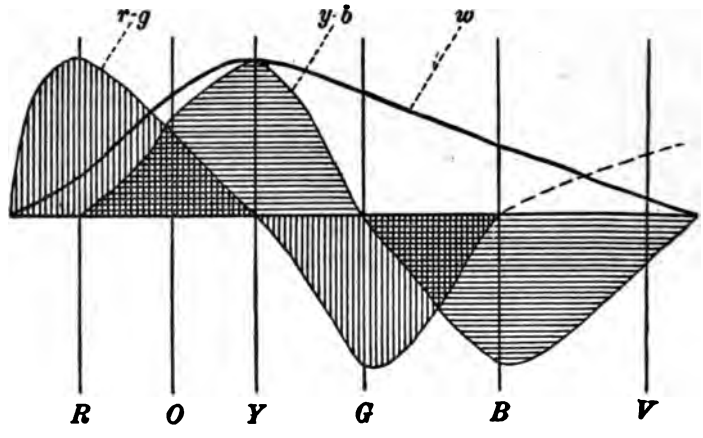


FIG. 3.—Diagram to illustrate Hering's theory of color vision. The red-green substance, *r–g*, is vertically shaded; and the yellow-blue substance, *y–b*, is transversely shaded.

or the red and the green substances may be imperfectly segregated, as assumed by Mrs. Franklin's theory. The close relation between the red and green substances is shown in Koenig's presentation of the Young-Helmholtz theory. (Fig. 5.) The absence of either would give rise to somewhat similar conditions, such as occur in protanopia and deuteranopia. The figure indicates that in trichromatic vision, the colors from yellow to blue affect all three substances to a certain extent, thus adding a small amount of white to the color sensation. In dichromatic vision the mixing of the two elements yields white. In case the red substance is absent, this white will appear nearer the blue than in case the green is absent: its position is indicated by the intersection of the blue with the green and red curves, respectively. In the absence of the blue substance, the white band is near the yellow. This accords with the

observations upon the color blind. The absence of the green substance would not shorten the spectrum, but the lack of the red or blue would cut off their respective ends. All of these features are equally well explained if, instead of the absence of one of the three substances, such a modification of its reaction is assumed as would be illustrated by a lateral shifting of its curve in the diagram. Thus in red blindness the red curve is shifted to cover more closely the territory of the green; in green blindness the green is shifted toward the red; and in the blue blindness the blue and green curves are brought together. Thus in the color blind all three substances are present but in modified form. Since this modified Young-Helmholtz theory accords so well with observations on color blindness, it is generally considered as the most satisfactory explanation of color vision.

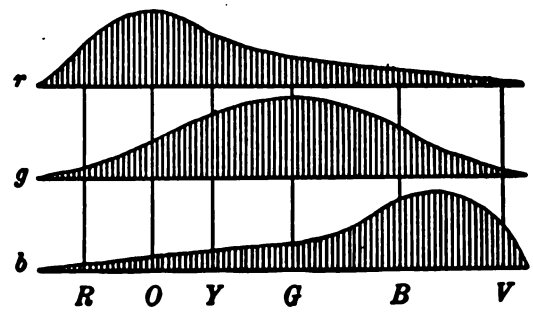


FIG. 4.—Diagram to illustrate the Young-Hemholtz theory. *r*, *g*, *b*, red, green, and blue perceiving substances, respectively.

An interesting attempt has been made by Patten to bring this theory into relation with structural elements in the cones.[a] He believes that the visual cells of invertebrates are characterized by a fibrillation which is transverse to the direction of the incident light waves, and that the tendency of the vertebrate rods and cones to separate into transverse disks is evidence of a similar structure. Many hundreds of such fibrils may exist in a rod or cone. They are not supposed to vibrate like tense strings, but to act as "conductors or resonators," a fact which would not exclu

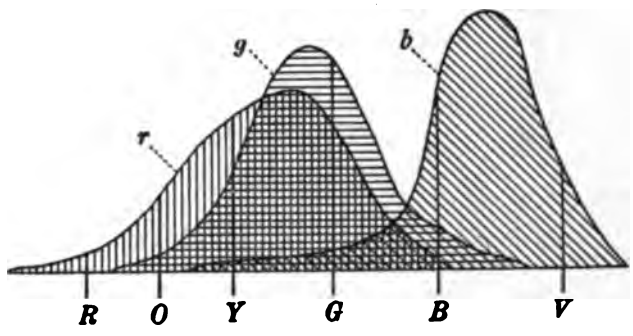


FIG. 5.—A modified diagram of the Young-Helmholtz theory, after Kœnig.

[a] Patten, W. A basis for a theory of color vision. *J*
pp. 833–837.

changes resulting in fatigue. The long fibrils respond to the red end of the spectrum and the short ones to the blue. In rods the fibers are of equal length and only monochromatic vision is possible, but in the cones their varying length allows a range of color perception. Any variation in the form or dimensions of the cones would bring about corresponding changes in vision. The increased length of the cones at the fovea provides for a greater power of color discrimination. If the base of a cone were absent or cylindrical it would be red blind.

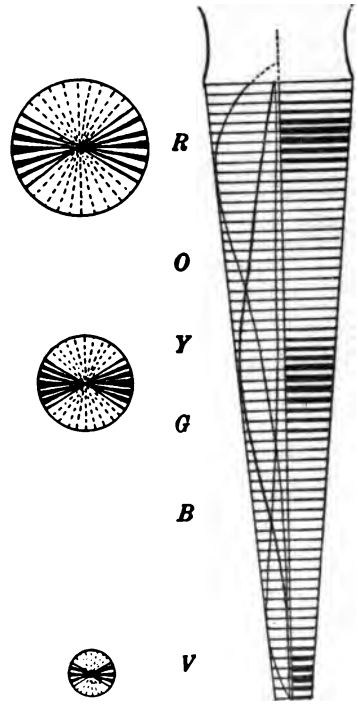
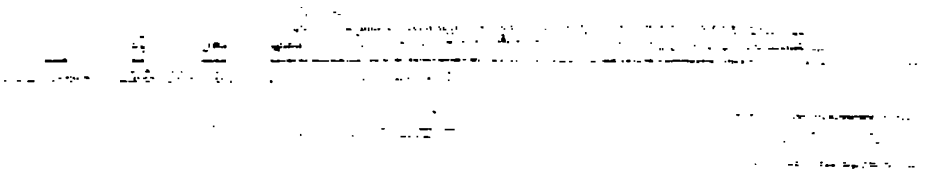


FIG. 6.—Diagram to illustrate the supposed fibrillar structure of human cones, and the way in which various light waves affect them. (Patten.)

This theory is illustrated in figure 6. On the right is the diagram of a cone and its fibrils; the latter radiate from an axial filament, the existence of which has been discussed and denied by other investigators. The fibrils in the right half of the cone are drawn as responding to red, yellowish green, and violet light; the Young-Helmholtz curves are shown on the left. In nonpolarized light all of the fibrils in a transverse section of a cone respond uniformly, but in polarized light only such are affected as are indicated in the cross sections on the left of the figure. Thus the dullness of polarized light is explained. The correctness of this supposition, as Doctor Patten states, will be determined by extensive measurements, much more accurate and detailed than any heretofore made, of the visual elements in all classes of animals.

It will be noted that according to Patten's and Mrs. Franklin's theories the mechanism for reaction to all the colors may exist in a single cone. The Hering theory calls for the reaction to at least two colors in one cone; but, according to the Young-Helmholtz theory, although the three substances could exist in a single cone, each is declared to exist in a cone by itself. This is considered to be strongly in favor of the validity of the Young-Helmholtz theory. Since physiologists find no instance in which different sorts of impulses are conveyed over a given nerve fiber, it is believed that a single cone fiber can transmit only one sort of color sensation. The stimuli of the red, green, and blue cones respectively are supposed

to be gathered by separate nerve cells of the retina, and the optic nerve consequently contains certain fibers transmitting only red, green, and blue sensations respectively. The mixing of the sensations, giving rise to the perception of shades and tints, is therefore accomplished in the brain and not in the cones. In an attempt to test this supposition, attention has been called to the perception of the colors of stars. The image of the star is so minute that it would cover but a single cone, but the conclusion that one cone perceives its color is invalidated by the fact that the retina is not sufficiently stationary; the image of the star falls in rapid succession upon several cones which may unite in giving the color perception. Those who believe in the specific energy of the rod and cone fibers dismiss at once several of the theories of color vision. It must be remembered, however, that the separation of the cones into forms responding to red, blue, and green light, with three corresponding sets of nerve cells and fibers to convey these separate stimuli to the brain, does not rest upon anatomical evidence.



IMMUNITY IN TUBERCULOSIS.[a]

By SIMON FLEXNER, M. D.,
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I can not begin this address without delaying a moment to testify to my sense of the great honor which has been conferred upon me by your invitation. Neither can I proceed with it until I have expressed to you my conviction that there are persons present in this audience whose scientific work on tuberculosis makes them far abler than I to discuss the complex problem of immunity in tuberculosis. My work in bacteriology in the past has not led me to an especial consideration of the highly important problem of the prevention and cure of tuberculosis, and I can therefore account in no other way for my selection to address you this evening than that you desired this topic presented to you from the point of view of one who has done some work in the general field of bacteriology.

The modern study of tuberculosis, as you know, begins with the generation which immediately preceded the epoch-making discoveries of Koch. It may, I think, be said with justice that this study was inaugurated by the first purposeful transmission by inoculation of the disease from animal to animal. For whatever may have been the speculations upon the infectious and transmissible character of the disease before this demonstration, yet the demonstration was necessary before further steps in the elucidation of the cause and prevention of the disease could be taken. Koch in his masterful monograph gives the credit of successful inoculation to Klencke, who in the year 1843 succeeded in inducing an extensive tuberculosis of the lungs and liver in rabbits by inoculation with portions of miliary and infiltrating tubercles from man. Klencke, after accomplishing this result, did not continue his investigations, and they were consequently soon forgotten. In the meantime Villemin's experimental investiga-

[a] Address delivered at the joint meeting of the Association of American Physicians and the National Association for the Study and Prevention of Tuberculosis, held at Washington, D. C., May 16, 1906. Reprinted, by permission, from the transactions of the second meeting of the National Association for the Study and Prevention of Tuberculosis, 1906.

tions were begun and pursued to a successful termination. inoculated not only with tubercular material from human beings, also from cases of bovine tuberculosis, and he seemed to have pro experimentally the identity of the latter disease with human tu culosis. Villemin's researches, from the number of his experime the careful manner in which they were carried out and the emp ment of suitable control experiments, appeared to decide the ques in favor of the infective theory of tuberculosis. The numer workers who repeated Villemin's experiments, after the same modified methods, arrived at very contradictory results. The ponents of the infective theory strove to prove that true tubercul could be induced by inoculation with *nontubercular* material. the decision of this question Cohnheim and Salomonsen contribu largely by selecting for inoculation the anterior chamber of a rabl eye. The great advantage which this method possesses over all otl arises from the fact that the course of a successful tubercular inoc tion can be watched throughout by the experimenter until pathological process has advanced so far that the whole organis the neighboring lymphatic glands, the lungs, spleen, liver, and neys—becomes tuberculous.

A further point in favor of this method of inoculation is spontaneous tuberculosis of the eye has never been observed in rabl It was reserved for the genius of Robert Koch to discover ne twenty years later, in 1882, by the employment first of an orig staining method, the tubercle bacillus in sections of tubercu organs, and next by the use of a special method of artificial cult tion, to secure growths of the bacillus free from all admixture extraneous matter. With these pure cultivations he succeeded you well know, in reproducing in certain domestic animals all characteristic appearances of tuberculosis in man. Furtherm Koch's studies of this period convinced him of the unity of causa of the various tubercular affections met with in man and also of t met with in the common domestic animals. Refusing to be dau by the fact that tuberculosis tends to appear under different asp in each species, and directing his attention not upon the gross pearances of the disease, but focusing it upon the microscop appearances of the primary tubercle, which as he said recurs v typical regularity in all the different processes in man, Koch rec nized the essential identity of the apparently widely different fo of tuberculosis in the various species of animals. It does not det from the immense value of his work that Koch failed to distingu between the tubercle bacilli isolated from the tubercular tissue fowls, cattle, and man. This failure was by no means accidental, the possibility of the existence of differences in nature of the cultu depending upon their origins was clearly in his mind Many of

will recall the long list of cultures which is given in the paper on tuberculosis published in 1884. In regard to this list Koch says: "It may cause some surprise that so relatively large a number of cultures was set on foot when a few would have sufficed for observing the behavior of bacilli in cultures. It seemed to me, however, not improbable that though bacilli from varying forms of tuberculosis—perlsucht, lupus, phthisis, etc., presented no differences microscopically, yet, that in cultures differences might become apparent between bacilli from different sources. But although I devoted the greatest attention to this point, I could find nothing of the kind. In all the cultures, whether taken from miliary tubercles, lupus, or perlsucht, the tubercle bacilli behaved exactly the same."

Our knowledge of the nature of the tubercle bacillus has been increased until at this time several distinct kinds are recognized. These may conveniently be classified according to their chief sources into human, bovine, and avian tubercle bacilli, and into so-called tubercle bacilli of cold-blooded animals. This last group of bacilli, which will detain us only a short time, differs greatly from the other varieties, as can readily be seen when the fact is recalled that the high temperatures—temperatures approaching blood heat—which are required for the growth of the mammalian and avian bacilli, quite preclude their multiplication under conditions of ordinary external nature. Hence they are not adapted to a life outside the living body except as cultivated artificially at this relatively high temperature. In man's conflict with tuberculosis this fact is of the greatest service, since by reason of it he is enabled to disregard the danger of any increase in tubercle bacilli outside the animal body. The relatively low temperatures at which the tubercle bacilli of cold-blooded animals develop adapt them, indeed, to an independent existence; but, as they are wholly devoid of power to cause disease in warm-blooded animals and as they would appear to have a restricted dissemination even among cold-blooded species, they are of comparatively small importance.

Of far greater consequence is the question whether the disparity which exists between the several kinds of tubercle bacilli derived from warm-blooded animals is a wide one. This question, which at first sight may appear to be chiefly of academic interest, has, in reality, far-reaching practical significance. The close relationship which man bears to domestic animals makes every fact of animal disease of high value to him. And in the case of no animal disease are facts of greater moment than in tuberculosis. Not only is the human race, by reason of its dependence upon the animal kingdom for food, work, etc., exposed to the diseases of animals which are transmissible to man, but domestic animals are also exposed to diseases of human beings. This correlative susceptibility may, therefore, cooperate to produce a

vicious circle of events by which infection or the dangers of infection are kept alive and threatening. Hence it is that an effective solution of the problem of limitation of tuberculosis, whether by suppression outright or by suppression through the induction of immunity, must take into account the degree to which tuberculous animals of different species, through direct or more remote association, are a source of danger to one another.

There is no longer any doubt that the avian tubercle bacillus departs considerably from the human and from the bovine types of bacilli. The early observations of the Italian investigators, Rivolta and Mafucci, have been confirmed and so extended as to give us a fairly comprehensive knowledge of the capacities for pathogenic action, upon different animal species, of the avian bacilli. At the same time painstaking studies of the degree to which birds are subject to inoculation with pure cultures of tubercle bacilli of human origin support the view of diversity in type of bacilli and susceptibility of species. And yet, while fowl react only with slight local lesions, as a rule, to inoculations of tubercle bacilli of human origin, certain mammals have proved themselves fairly subject to experimental inoculation with avian bacilli. While the guinea pig, otherwise so sensitive to inoculation tuberculosis with the mammalian bacilli, is relatively resistant to the avian variety, the rabbit, which exhibits a marked degree of refractoriness to the human bacilli, succumbs quite readily to the avian bacilli. It is, however, worth noting that the reactions in the rabbit which avian tubercle bacilli call forth do not conform to those observed in tuberculosis in general; there is absence of typical tubercles and caseation, and the chief pathological alterations observed are found in connection with the enlarged spleen.

The literature on tuberculosis contains a small number of references to the cultivation from human subjects of the avian tubercle bacillus. From our present knowledge it may be postulated that avian tubercle bacilli occur rarely in man. Rabinowitsch has, indeed, recently emphasized the occasional occurrence of the avian bacilli in cattle, swine, horses, and monkeys; but they constitute a small source of danger in the spread of tuberculous disease among mammals. The parrot, because of its use as a pet and of its susceptibility to the avian bacillus, on the one hand, and of the human bacillus, on the other, is a greater menace to public welfare.

The subject of bovine tuberculosis and of bovine tubercle bacilli is among the most important of all the questions relating to the suppression of tuberculosis. The admirable studies of Theobald Smith established the distinction in type subsisting between certain bacilli of human and of bovine origin. We have come now to regard these types as separate and not to be transmuted, at least not readily under

artificial conditions of cultivation, into each other. Into the disputed questions of variation due to environment I can not afford to enter. But I would have you believe that transformations of avian, bovine, and human bacilli into each other have probably not been accomplished by experimentation. The cultivation of one variety of bacilli in the body of an alien species has been said to alter profoundly the properties of the bacilli; but the observations upon this point are in my opinion far from convincing. The mere fact that avian and bovine varieties of bacilli preserve their peculiar properties when occurring naturally in the diseased body of an alien species—man, for example—tends to discredit the experimental transmutations referred to.

Bovine tubercle bacilli are characterized, as ascertained by Smith, by a greater degree of pathogenic power for mammals in general than human bacilli, with which fact is correlated certain peculiarities of cultural and physiological properties serving further to separate the bovine from the human bacilli. The bacilli of mammalian origin are, perhaps, closely related and less removed from each other by the sum of their properties than they are from the avian bacillus. With the few exceptions mentioned all forms of mammalian tuberculosis are caused by either the human or the bovine bacillus.

In view of the general fact that the bovine bacilli show a greater degree of pathogenic action for the lower mammals than the human bacilli, it was natural to assume that bovine bacilli would be powerfully pathogenic for man also. To test this probability directly by experiment is, of course, not permissible. But the belief that tuberculosis in cattle is a menace to man is expressed in the many regulations by which it is aimed to control and prevent the use as food of products derived from tuberculous animals. It was not until Koch's address was delivered in 1901 that any serious doubt existed in the minds of sanitarians and pathologists that tuberculous cattle offered a source of danger to man. The specific knowledge which has accumulated since that date has served to establish the transmissibility in some degree of bovine tuberculosis to the human subject. The inherent difficulty and tediousness of the investigation of the specific types of tubercle bacilli existing in human cases of tuberculosis necessarily limit the total number of instances in which it has been established, beyond peradventure, that the bovine type of bacillus does occur in tuberculous processes in man. In this country the responsibility of refuting the too general statement of Koch has fallen chiefly upon Ravenel and Theobald Smith, whose admirable studies in this direction are of a convincing nature.

If we pause for a moment to consider upon what data Koch based his statement of the independence and noncommunicability of tuberculosis in cattle and man, we shall appreciate that, in so far as he dealt

with established fact and not hypothesis, he had long been anticipated. That cattle are highly resistant to infection with tuberculous material and tubercle cultures obtained from human subjects can be concluded from the early experiments of Baumgarten, Sidney Martin, Frothingham, and Dinwiddie. The most conclusive evidence upon this subject is contained in Theobald Smith's paper of 1898, in which he summarizes his experiments by stating that "putting all the facts obtained by experiments on cattle together, it would seem as though the sputum bacillus can not gain lodgment in cattle through the ordinary channels." In view of these facts, it is not surprising to find that Koch and Schütz later failed to produce marked or general tubercular infection of cattle by feeding or inoculating directly into the circulation tuberculous materials and cultures of tubercle bacilli of human origin. That this result does not dispose of the entire question at issue, but leaves open the important consideration of the implantation of the more virulent bovine bacilli upon man, was, of course, present in Koch's mind, and was met by him by emphasizing the infrequency with which primary intestinal tuberculosis, which is the form of tuberculosis presumably arising from ingested virulent tubercle bacilli, is encountered in human beings. The reports which have appeared since have tended to show that primary tuberculosis of the abdominal viscera, especially in children, is not so infrequent as Koch believed it, and the researches inspired by Koch's address have brought out the important fact, now based upon actual observation under the microscope, that tubercle bacilli may pass through the intact intestinal wall and reach, by means of the lymph current, the mesenteric glands; and have made it seem probable, also, that by entering or being carried into the blood vessels in the intestine the bacilli may be carried to the lungs. When all the known facts of food infection in tuberculosis are assembled, they make quite an imposing array, for they indicate, quite in opposition to the exclusive view expressed by Koch, that tubercle bacilli entering the body with food may be implanted upon the mucous membrane of the mouth, from which, probably, chiefly in the region of the tonsils, they may be carried to the lymphatic glands of the neck and adjacent parts, where they develop and produce tubercular disease; or they become implanted upon the intestinal mucosa and pass the epithelial barrier without first causing disease there, and set up lesions in the mesenteric lymph nodes or even be transported by the blood or lymph to the distant lungs; or they may first multiply in the intestine, cause tubercular disease there, and then migrate further, involving the abdominal and thoracic organs.

If I have seemed to tarry too long over this aspect of my subject, I will ask you to consider for a moment in how far the endeavor to limit the spread of tuberculosis among the human race must be influenced by the avenues of infection to which the race is exposed.

If we side with Koch in the view expressed in 1901, and reiterated just the other day in his Nobel prize address, that, as he says, human tuberculosis and tuberculosis in cattle are so distinct from each other that the latter is not to be feared as transmissible to man, at least, as his last utterance puts it, not in a form which comes in consideration in regard to tuberculosis as a "Volkskrankheit," or race disease, then it is only necessary to direct efforts to the suppression of tubercle bacilli of human origin. For, if the danger of infection of surroundings and healthy individuals is limited to the expectoration of persons suffering from tuberculosis of the lungs and upper air passages, the problem before us, while still very large, is less by a considerable amount than if there must also be taken into account the widely prevalent disease among cattle, swine, and other domestic animals. While I do not pretend to speak in terms of great authority, yet it would seem to me that the time is not yet ripe to disregard, in attempting to suppress tuberculosis, the disease in domestic animals. Greatly as I sympathize with the active propaganda which is being made by instruction and material help to protect tuberculous human beings from injuring themselves and others, and greatly as I hope to see promoted the means of caring for the tuberculous in sanatoria, etc., yet I hope that there may occur, at this time, no relaxation in in the efforts being made to control the spread of tuberculosis among cattle and to prevent the consumption of infected milk and flesh by man and other animals. That, on the other hand, the suppression completely of tuberculosis among cattle would not be followed by a great reduction in the morbidity due to tuberculosis in man is shown by Kitasato's statistics from Japan. In that country the human disease prevailed with its usual activity at a time when the cattle disease, owing to the absence of cattle, was unknown, and milk formed no appreciable element in the food of children.

In dealing with the complex problem of tuberculosis—a problem whose difficulties enlarge with the continued growth in size of cities—we are materially assisted by the knowledge of the manner in which the virus of tubercle is separated from the diseased body, the conditions of its contamination of our environment, and the avenues through which it endeavors to enter the healthy body. Though it is, perhaps, scarcely to be hoped that a time will arrive when tuberculosis will have become, through precautions against infection, as rare as are to-day smallpox and typhus fever, yet it is a most hopeful result of the crusade against tuberculosis that a marked reduction in the mortality, and probably in the incidence of the disease, has been going on in some countries—as, for instance, in England—for forty years. In New York, the system organized by Biggs has brought about a reduction since 1886 of 35 per cent in the mortality of the disease; [illegible] while in Prussia the mortality was stationary in the decade from

1876 to 1886, since that time a reduction of more than 30 per cent ha been noted. These figures show what may be accomplished in redu ing the dangers of infection with tuberculosis by a régime of educa tion, improved conditions of living for the poorer classes, and th segregation in hospitals and sanitoria of any considerable number c the infective tuberculous during the most dangerous period of th disease.

The discovery of the microbic agent of tuberculosis naturall awakened the hope that a specific means of treating and, possibly, o preventing tuberculosis might now be found. The early years follow ing the cultivation of the tubercle bacillus saw no realization of thi hope, and to-day we are still far from the desired goal. However, th prodigious labor which has been expended in the search for a mean of protection against infection with the tubercle poison has not bee wholly devoid of results.

In an address of this kind it is not practicable to deal with th separate contributions, in detail, which the many workers have mad to the subject of immunity in tuberculosis. The most that can b accomplished is to bring together the more important results of al the workers and, after having assembled them, to judge of their valu and to consider, possibly, in what important respects they are stil imperfect. I can not do better, at the beginning, than to remind yo that the successful point of departure has been the discovery tha variations in type and in virulence exist among tubercle bacilli. Th earlier view which taught that the tubercle bacillus is a micro organism of uniform and fixed virulence has been shown to be erro neous, first by the discovery of variations according to certain origins and second by a gradual decline in pathogenic power suffered b certain strains through long cultivation outside the animal body.

The animals which have been of special use for tests of immunit are rabbits, cattle, and goats. The guinea pig, which furnishes a almost ideal animal for the detection of tuberculosis, because of th sensitiveness of its reaction to inoculations with tubercular materia fails, for the same reason, to be a highly suitable animal in which t carry out tests of immunity; and yet it has been employed with som success.

The first important contribution to the subject of experiments immunity in tuberculosis was made by Koch in connection with hi researches on tuberculin—a product of the growth in broth of tubercl bacilli, freed from the bacilli and concentrated. In spite of th failure of tuberculin to bring about a favorable issue in all cases o human tuberculosis in which it is administered, it still remains a useful, perhaps the most useful, strictly medicinal agent employed fo the treatment of tuberculosis. But the sum of its useful properties i not embraced in its employment as a therapeutic substance; it is als

a diagnostic agent of high value, and its action upon the tuberculosis organism is so specific and remarkable that it has proved itself of the greatest importance and aid in the effort to unravel the complicated series of biological phenomena which constitute the tubercular state.

It is possible to increase somewhat the resistance of animals to tubercular infection by previous treatment of tuberculin; but this increase is not remarkable. It is possible to bring about arrest of the tubercular process in the infected organism by means of tuberculin; and in some instances this arrest leads, through the changes induced in the tuberculous tissue by means of the tuberculin injections, directly to cure, or indirectly, through an increased power of resistance and attack on the part of the forces of the organism, to eventual cure. But a high and lasting degree of immunity has never been secured by the use of tuberculin. This fact, disappointing as it was at first, is now easily explicable. Tuberculin does not represent the entire series of forces contained in the bacilli which the body has to resist in preserving itself from infection with tubercular poison. The peculiar principles contained in tuberculin are, indeed, not highly toxic for the normal individual; and our experience in securing immunity to microparasites and their products has taught us that where no reaction or response to the introduction of the foreign poison is called forth, no degree of protection to larger doses or more virulent poisons of the same nature is to be expected. Toxic as is tuberculin to the tuberculous organism, it is almost innocuous to the tubercle-free body. It has been found, in keeping with this distinction, that the normal animal shows after tuberculin treatment evidence of the minimal production of the neutralizing or antibody for the tuberculin, which, were tuberculin a direct poison for the tissues, would probably be produced in larger amounts. On account of this absence of action on the normal organism it has been thought that the active principle in tuberculin does not exist in a free state, but occurs in some combination, from which the tuberculous, but not the nontuberculous, organism can free it, and that the separation takes place in the tubercular foci upon which the specific action of the poison is directly exerted. If this view is correct then the failure of tuberculin to exercise any profound action on the healthy organism is easily grasped.

Increased knowledge of bacterial infection and immunity has taught us that in case of bacteria which invade the depth of the body and produce their peculiar effects by reason of their immediate presence, we can not expect to achieve marked immunity through the use of the soluble gross products of the parasites. The reaction of the body to the invasion depends not upon the presence in the invader of one set of toxic principles, but of many, some of which are contained in the solid substance of the micro-parasite and do not go over into the fluids in which they multiply. Thus it has been found, in case of

certain bacteria, that a degree of immunity or protection which it impossible to obtain even after very prolonged treatment with fluid portions of cultures, can be secured quickly when small qu tities of the living or even dead micro-organism are injected into body. A high degree of bacterial immunity has been secured up now for a small number of micro-organisms by vaccination—by method introduced by Pasteur—for several animal diseases, nota anthrax or splenic fever, fowl cholera, and black-leg. In these ca the living attenuated micro-organisms are employed.

Neither lasting nor marked immunity in tuberculosis can be tained by the inoculation of cultures of tubercle bacilli killed by h sunlight, or other agency. Dead tubercle bacilli are poisonous bring out a striking reaction of the organism, but this reaction d not confer immunity to subsequent inoculations of the living ge It may well be that the dead bacilli, especially if reduced to palpable powder so as to facilitate absorption, may after inject raise the powers of resistance in the organic forces, although height of the sustained forces is not sufficient to enable the body throw off completely the living infecting organism. It is easy prove that the animal organism is modified by the development wit it of the tubercle bacilli; and merely disposing of dead bacilli creases its power of reaction against a second injection of d tubercle bacilli; the second action being much more vigorous than first. The experiments of Koch which immediately preceded the covery of tuberculin clearly demonstrated that tuberculous gui pigs into which tubercle bacilli are reintroduced subcutaneously re in a very especial manner. An active inflammatory process devel about the site of second inoculation which eventually brings about expulsion of bacilli with the exudations; a voluminous slough for which, when shed, carries with it a large number of bacilli; and t shedding is followed neither by the formation of a permanent ul nor hypertrophy of the neighboring glands, a regular result of primary inoculation. The tubercular organism reacts in the sa manner to dead as to living bacilli; the tuberculous animal has quired immunity against reinfection or reintoxication by the tuber lous virus, which, however, in no way prevents the first inoculati from becoming generalized and setting up a tuberculosis of almost the organs.

If we attempt an interpretation of these phenomena we can c clude that the organism, once it is poisoned with tubercle vir becomes supersensitive to the tubercle poiso[illegible] his supersensiti ness is displayed in the mar[illegible]ion [illegible]ulation of t tuberculous organism to t[illegible] [illegible]ng tuber bacilli. But the organism [illegible]lli is n in reality tuberculous; it [illegible]wi

this distinction, it can be said that while the tuberculous organism has acquired a degree of immunity to reinfection, the organism merely poisoned with tubercle bacilli has failed to develop this state of resistance.

The experimental results, which I shall relate to you, upon which are based our belief in the artificial production of immunity to tuberculosis, were all obtained by the use of living bacilli. It would, therefore, seem as if in the course of their residence and development within the body the immunizing organisms behave differently from those in artificial cultivations. This difference in behavior could be accounted for on the supposition that under conditions of parasitic life, surrounded as the bacilli are with complex fluids and more complex cells, they form, in their growth, products which either are distinct from those which are formed by them in cultures, or these products, in *statu nascendi*, are acted upon and modified by the active and labile ferments in the fluid and protoplasm of cells, with which the growth-products must come into immediate contact. Professor Welch, to whom this variation in behavior of bacteria under parasitic and saprophytic states of existence was fully apparent, endeavored a few years ago in his Huxley lecture to explain the difference in activity of bacteria growing within and outside the body by supposing that in the body they are induced to secrete substances the stimulus to the production of which is absent in the culture tube. However this may be, it is evident that the only form of immunity in tuberculosis which deserves the name has been obtained by the employment for inoculation of living cultures of the tubercle bacillus.

Although the earliest experiments which had for their object the production of immunity in small animals by means of previous inoculation of products of the growth and of attenuated cultures of the tubercle bacillus were published in 1890 (Martin and Grancher, Courmont and Dor), yet, I think, the first really promising, because successful, achievements of this end were made by Trudeau in 1902 and 1903 and by De Schweinitz in 1904.

Trudeau protected rabbits from virulent tubercle bacilli by first injecting them with a culture of bird tubercle bacilli, the subsequent injection of virulent mammalian bacilli being made into the anterior chamber of the eye. The rabbits to be protected were twice injected subcutaneously at intervals of twenty-one days with cultures of the avian bacilli. About one in four of the rabbits died within three months, profoundly emaciated, but without tubercular lesions. The remaining animals recovered and were apparently in good health, when, with an equal number of controls, they were inoculated in the eye with a culture of mammalian tubercle bacilli. The results are instructive: In the controls little or no irritation following the operation is observed and the eye remains quiescent or nearly so for about

two weeks, when the changes described in the early parts of address manifest themselves. After a few weeks general inflan tion of the structures of the eye develops, the inoculation wc becomes cheesy and the eye is more or less completely destrc The disease, however, remains usually localized in the eye for n months, and may remain there permanently, depending upon virulence and number of bacilli injected.

In the vaccinated animals, on the contrary, the introduction o: mammalian bacilli at once gives rise to a marked degree of irrita From the second to the fifth day the vessels of the conjunctiva be engorged, and evidences of marked inflammation appear in the terior chamber and on the iris (reaction of immunity). How at the end of the second to the third week, when the eyes of the trols begin to show progressive and steadily increasing evidenc inflammatory reaction, the irritation in those of the vaccinated mals begins slowly to subside and the eyes to mend. In fron to twelve weeks, in the successful cases, all irritation has disappe and the eyes present only the evidences of traumatism and inflan tion. This experiment leaves no doubt of the protective influ exerted by the first inoculations of the avian bacilli and clearly e: lishes that related cultures of tubercle bacilli of moderate virul for an animal species can afford protection to subsequent inocul: with special and more pathogenic strains of the bacillus. Notv standing the fact that, as Trudeau records, some of the prote animals slowly relapse and the disease resumes its progress, althc by almost imperceptible stages, the experiment still shows that tection, not absolute immunity, from tuberculosis may be obtaine rabbits by a species of vaccination.

De Schweinitz in 1894 reported certain experiments which he n on guinea pigs and cattle. He inoculated the former with a cul of tubercle bacilli of human origin cultivated for about twenty erations in broth. This culture was of a low grade of virulence these animals, but it served to protect them to such an extent that w they were afterwards inoculated with tuberculous material fro: cow they remained healthy, while control pigs injected with the s material became tuberculous and succumbed in about seven we De Schweinitz injected large quantities of human tubercle bacilli cattle—beneath the skin, into the peritoneal cavity and into the ci: lation—without injury.

I may, at this time, digress for a moment and leave the n strictly chronological method of presentation to allude to the se experiments on the protection of guinea pigs from tuberculosis wl Trudeau reported to the National Tuberculosis Association at its meeting. The special merit of this experiment is that it shows the istence of a connection between virulence and infectivity in the g

and its capacity to confer immunity. Unless the bacillus has the power to gain some foothold in the body it affords no protection; if on account of high pathogenic power or virulence it easily gains a foothold, then it brings about infection. To choose a culture of tubercle bacilli of just the right grade of virulence is one of the conditions, apparently, of successful experiment, as it must also be, in view of this fact, one of the difficulties of the method. The same difficulty has been encountered in the practical carrying out of this method of immunization in cattle. Several series of guinea pigs were inoculated with tubercle bacilli as follows: (*a*) With dead bacilli, (*b*) with living bacilli from cold-blooded animals, (*c*) with a culture of human bacilli cultivated artificially for more than twenty years which produces on inoculation no appreciable local lesions and never tends to generalize, and (*d*) another human culture cultivated artificially for more than fourteen years, which still causes in all the pigs slightly enlarged inguinal glands near the site of inoculation, and occasionally brings about slight caseation of the nodes with a tendency to partial generalization of the virus. The dead bacilli and the bacilli from cold-blooded species gave no protection; the second human culture, by reason of its greater invasive properties, protects better than the first, which is almost devoid of power to grow in the animal body. In no case, however, was the growth of the virulent bacilli wholly suppressed.

In man the question of acquired immunity has been answered by many authorities, as far as the main considerations go, in the negative. A large number of well-observed facts demonstrates that a person who has suffered from localized tuberculosis of the lymph glands—scrofula so-called—or other form of local tuberculosis, can not count upon an immunity from pulmonary tuberculosis. And yet it can, I think, be shown by reference to statistics that in man there exists a refractory condition which becomes increased after infection, since the number of persons who have been the victims, at some period of their life, of a tuberculous infection, is very large in comparison with the number who die of this disease, or the even larger number who develop severe forms of it. Hirsch gives the mortality of tuberculosis as compared with deaths from all other causes as 3:22; in other words, tuberculosis claims as victims of death one in every seven persons. This proportion does not, however, express the morbidity from tuberculosis, which is, in reality, far greater than these figures indicate. It is difficult to secure by vital statistics reliable data of the incidence of tuberculosis; but trustworthy observations made at autopsies upon human beings indicate that as many as 90 per cent of persons, dying from all causes, have at some period of their life been the victims of a tubercular infection. In far the greater number of instances the disease remains fixed in the bronchial or other lymphatic glands or

the apex of the lungs and exerts no injurious effect upon the organism as a whole. We may, therefore, fairly conclude that the human organism possesses a strong inherent tendency to overcome infection with the tubercle bacillus. So much can be safely predicated. But whether the suppression of a local infection, such as I have described, gives an increased capacity for overcoming subsequently invading tubercle bacilli remains for the present an open question. It is certainly not disproved by the facts cited; and some authorities hold fast by the belief that a degree of immunity to tuberculosis may be acquired by man.

In the year 1901, on December 12, on the occasion of his acceptance of one of the Nobel prizes, Behring announced that he was engaged upon the study of artificial immunization of cattle to tuberculosis. In this address the claim was made that a method had been perfected whereby it was possible to vaccinate cattle successfully against tuberculosis. These experiments consisted in the endeavor to immunize cattle by means of tuberculin, other toxins, so called, from the tubercle bacillus, dead tubercle bacilli, bacilli weakened with chemicals and living, active cultures of the tubercle bacillus. In the four years which have elapsed since this announcement was made a series of monographic papers bearing on this subject has appeared from Behring's laboratory in Marburg. The plan of immunization has, in this time, undergone a number of modifications until now it consists in the inoculation intravenously of young cattle—calves twelve weeks old preferably—with a standard human culture, which is now furnished commercially. A second inoculation of an increased quantity of this culture is injected three months later. Cattle treated in this way are regarded as highly immune and are denominated by Behring as "Jennerized." If to them a dose of virulent bovine culture of tubercle bacilli is given, no permanently bad results follow, although an equal dose of the virulent culture will cause, in an unvaccinated animal, the development of generalized tuberculosis leading, in a few weeks, to death.

In his endeavor to find a culture of the tubercle bacillus which would fulfill the requirement of producing a transient illness and leave protection behind, Behring discovered that not all tubercle bacilli of human origin were without danger to cattle inoculated with them. We were, indeed, not unprepared for this announcement, since, in the first place, we had learned that in some instances tubercle bacilli of the bovine type have been cultivated from examples of human tuberculosis, and, on the other, that not all the bacilli, of any type, exhibit equal degrees of virulence. The culture employed by Behring, although it has now been employed to inoculate several thousand cattle, is said never to have produced severe disturbances of health; even when animals already tuberculous are inoculated the

results are not serious: fever lasting several days sets in, the anim may cough, and they may eat less and lose somewhat in weight, even they return to what is for them the normal.

It would appear that McFadyean is entitled to the credit of discovery equally with Behring of the immunization of cattle agai tuberculosis; and, indeed, there is reason to believe that his resu even anticipated those of Behring. By using for injection first tul culin and then in succession tuberculin and tuberculous material c taining bovine and possibly human tubercle bacilli, McFady succeeded in increasing the resistance of several cattle to artifi tubercular infection.

Pearson and Gilliland, 1902, in this country early published ac counts of some experiments which they carried out upon the immu nization of cattle against tuberculosis. They employed a culture c human tubercle bacilli for producing immunity and found that sul sequently the protected animals, as compared with the controls, whic all succumbed to the virulent inoculation, either developed no lesion or very inconsiderable ones upon being given large quantities c highly pathogenic bovine cultures. As far as I know these exper menters are the only investigators who have endeavored to carry th principles of the method a step farther, so as to bring about arres of the disease in cattle already tuberculous. While it is unlikel that such a therapeutic use of " vaccination " will ever be made i veterinary practice, the facts are of considerable theoretical interes especially in view of the somewhat similar means employed to arres tuberculosis in man.

The immense importance to scientific agriculture of the matter o immunization of cattle against tuberculosis and the even greater col lateral interest which the subject has for man, as enlarging the pos sibilities of immunity even for him, have led to a discussion on th priority of the discovery between Neufeld, a pupil of Koch, an Behring. It would appear from Neufeld's writings that, while work ing under Koch's direction, he ascertained as early as 1900–1901 tha large animals—donkeys chiefly, but cattle also—could be protecte from artificial infection with virulent tubercle bacilli, always fatal to control animals, by previous treatment with tubercle vaccine, of which several different preparations were studied. It is not within the scope of this address to apportion the credit of priority; but in any case, assuming the facts to be as stated by the contestants, McFadyean should receive as great credit as either of the others, if not the chief credit. The principle which all the investigators employed is not new in experimental medicine, but has come to us from the genius of Pasteur. It may, however, be said that our knowledge of the tubercle bacillus and its varying activities had by the year 1900 become so much enlarged that the possibility of putting the facts of the newly

discovered properties to a practical test of immunity occurred to the several independent workers in bacteriology. There can, I think, be no doubt that Behring deserves the credit of making the protection of cattle from tuberculosis a feasible, practical object of study. This alone is a merit of no small order.

From the mere fact that cattle have been successfully protected from infection by the tubercle bacillus, even under the severest conditions of laboratory experiment, it can not be concluded that they will be equally refractory when exposed to the natural sources and modes of infection. In the laboratory the virulent infectious agent is brought into the animal by injection, under the skin, into the serous cavities or into the circulation, which are avenues through which in the natural disease infection rarely if ever takes place. And while this mode of introduction of the virulent bacilli into the body may, theoretically, be more severe than their introduction into the lungs with inhaled air, or into the stomach through infected stalls and food, yet the profound differences in the defenses of the body with which the bacilli come into conflict, under these different circumstances, may, after all, determine the issue in a manner quite contrary to our expectations. It is, therefore, of the highest interest to learn that in their later tests Behring and his coworkers exposed vaccinated cattle to stalls and herds which were known to be badly infected, with the result that at the time of the report, they had apparently escaped infection. I am enabled through the courtesy of a private communication from Doctor Pearson to state that cattle vaccinated by himself and Gilliland which were kept for two years under natural conditions of infection have not contracted tuberculosis, while the control animals, exposed to the same conditions, have all developed the disease, some dying spontaneously by reason of the severity of the infection. Doctor Pearson also informs me that their experiments indicate that the degree of resistance bears a rather definite relation to the number of vaccinations given the cattle. No cattle vaccinated three times with their standard vaccine—a living culture of tubercle bacilli of human origin—have developed tuberculous lesions even after two years' severe exposure. In their experience, two injections of Behring's vaccine do not always suffice for such heavy exposure as they employed.

As regards the question of duration of the protection, it may be said that Behring, basing his views on results of vaccination made three years before, expressed the belief in 1904 that it would endure during the life of the animal. As young healthy cattle are vaccinated before they fall victims to infected stalls and herds, it would seem as if infected herds might therefore gradually be replaced by healthy ones. The gain, this being true, would be almost incalculable to agriculture.

I am in the fortunate position of being able to bring before you a critical summary of the subjects just presented by one wholly conversant with its practical as well as its theoretical aspects. Through the courtesy of Dr. Leonard Pearson I have been enabled to read the advance sheets of a review on immunization in tuberculosis which will soon be issued from the Phipp's Institute. Doctor Pearson concludes that there appears to be no doubt that different cultures of human bacilli have different immunizing values. Some can not be used at all because they are of too high, and others, possibly, because they are of too low, virulence for cattle. There is also need for comparison in immunizing value of fresh cultures and cultures that have been dried in vacuum and reduced to powder. Some observations appear clearly and strongly to indicate that the fresh cultures are preferable. Although it has been shown that vaccination can be practiced so as to be entirely harmless to the animals, yet, on the other hand, it is not always unattended with danger. What is the shortest and most economical procedure for the protection of cattle on a large scale is still to be established. Only prolonged observation of carefully recorded results of vaccinations practiced on a large scale can settle this point. The question of duration of immunity is still an open one. It has been shown that the immunity endures a year. To say, at the present stage of the studies, that it will last during the entire life of an animal is to make a statement for which there is no experimental proof. Modes of vaccination, as illustrated by the intervals between the successive injections, differ greatly. Behring recommends an interval of three months, while others have obtained a high degree of immunity by repeated injection at short intervals. As artificial immunity is relative and not absolute it need not excite surprise that the immunity to the tubercle bacilli can be overcome by the injection of large quantities of active bacilli. What is desired in practice is a degree of immunity that will suffice to protect animals from acquiring the disease under natural, and consequently highly variable, conditions. In some herds, where the natural disease prevails in a mild form, a lower degree of immunity may suffice than in other herds, in which the disease is more severe and widespread. We are, therefore, at the beginning of this complex and highly important subject. These are Doctor Pearson's conclusions.

There is another aspect of this subject which demands attention. When it is recalled that immunity in cattle is obtained by the injection of living human tubercle bacilli the question arises whether this procedure is wholly free from danger to the consumers later of the flesh and milk of these cattle. It would appear that the human bacilli do not excite in cattle the tubercular lesions, in which doubtless the bacilli are so inclosed as to be, to a considerable degree, protected from perishing. It is equally true that as the living micro-organism

can not be replaced by dead ones in bringing about immunity, the immunizing process is in some way bound up with their survival and even, possibly, with a restricted multiplication. Hence it is necessary that we ascertain, first, how long the human bacilli survive in the organs of the vaccinated animals, and second, whether they are ever eliminated with the milk of cows. The observations already made upon these points are so few as at present not to be useful for any scientific deductions. But before the method is too implicitly relied upon these questions should be answered.

It is an interesting subject of speculation as to what the result will be when cattle in general, and possibly, man later, shall have been immunized to tuberculosis. Will the race of tubercle bacilli disappear in large measure from the world? This would indeed be a beneficent result. But Doctor Smith has pointed out in a recently delivered address that doubtless host and parasite eventually come to hold a kind of equilibrium to each other, and hence an increased degree or resistance in the former might tend to bring about that selection among the parasites through which races of greatly augmented power for invasion would be produced. If this were true, and he even suggests that the natural process of weeding out the weaker among the human race tends to this result, the parasite would try to keep up with the host as his resistance increased until a point was reached beyond which further enhancement of power was impossible. Would the higher animal or the lower vegetable organism finally claim the victory? We need perhaps at this moment not to relax our efforts to achieve a practical immunity for man as well as for animals because of this future danger. I am not aware that the smallpox germ has increased measurably in virulence since vaccination became general, but I would also add that a century is a small period of time in the life history of any living organism.

Before closing this address I should like to refer briefly to the new interest which has been excited in the use of tuberculin in the treatment of human tuberculosis by reason of the application to the study of tuberculosis of a method introduced by A. E. Wright, of London, whereby it is held that the exact effect of the tuberculin injection can be measured and controlled. The method consists in the determination of the capacity of the blood leucocytes to take up tubercle bacilli when the blood and the bacilli are brought together outside the body in a test tube. Wright and his pupils have worked out the normal power of the blood to cause the englobing of the bacilli; and they have noted a diminution of this capacity in the blood of many persons suffering from tuberculosis. They speak of this englobing capacity of the blood as "opsonic index," from the word meaning to prepare—to cater for; since the bacilli must first be prepared by substances in the blood serum before they can be ingested by leucocytes. The in-

jection of tuberculin, when cautiously done, tends to bring about a rise in the tuberculous, of the "opsonic index," which Wright believes is a measure of the good done, as an increase in immunizing substances in the blood is the cause of the rise. He also discovered that time is required for the occurrence of the rise and that the immediate result of the injection is a fall of the index—so-called negative phase. This latter must be permitted to pass away and be succeeded by the positive phase before another injection is given. Gradually the "opsonic index" is driven up in the cases that are favorable to the treatment.

I do not intend to discuss the value to the clinician of this interesting method and Wright's observations based upon it. The subject appears to me to be one of great intricacy and therefore to be approached in a spirit of proper criticism despite its evident allurements. My purpose in mentioning it at all is to bring again to your attention a method of exciting the tuberculous body to put forth an effort at self-immunization which is sometimes efficient to a marked degree. It is not the injected tuberculin that accomplishes directly the changes in the condition of the patient, for there already exists, doubtless, an excess of similar poisons in the tuberculous foci in the body. The healthy body, indeed, does not react in this manner and is not to be protected, enduringly, from tuberculous infection by a previous treatment with tuberculin. As Koch's phenomenon shows the tuberculous organism to have developed defenses against subsequent tuberculous infection which the normal body does not possess in equal degree, the employment of tuberculin indicates that the diseased body can be aroused artificially to put forth a stronger effort than its unaided natural forces enable it to make, in order that the disease may be overcome. Herein resides a great principle, an immense power for good, and, consequently, a great hope for future progress in the rational and specific treatment of tuberculosis in man. Efficient efforts at suppression of the causes of tuberculosis, deeper knowledge of the principles of bacterial immunity, are the two forces which in time may stay the ravages of the "White Death."

THE AIR OF THE NEW YORK SUBWAY PRIOR TO 1906.[a]

By GEORGE A. SOPER.

INTRODUCTION.

The object of this paper is to record some hitherto unpublished facts concerning the quality of the air of the New York subway before any material change was made in its ventilating arrangements, and to seek to explain the essential conditions which controlled it. The investigation was made by me in 1905 at the request of the Board of Rapid Transit Railroad Commissioners for the city of New York.

The principal questions investigated related to temperature, humidity, odor, bacteria, and dust. The conditions found in the subway were compared with the conditions found in the streets through which the subway runs, and occasionally with conditions in other places.

In all, there were about 2,200 chemical analyses of air, 3,000 determinations of bacteria, and about 400 other analyses in special studies of dusts, oils, disinfectants, and other substances. About 50,000 separate determinations of temperature and humidity were made prior to the adoption of a system for automatically and continuously recording temperatures throughout the length of the subway and in the streets.

The methods employed in studying the different topics were, for the most part, such as had been used in other sanitary and meteorological investigations in which a considerable degree of accuracy was required. It is not claimed that they would have been the best to adopt in a purely scientific research. It was necessary to design them for practical as well as accurate use.

For the most part, the air to be analyzed was collected at an elevation of 18 inches to 2 feet above the pavement. This height was decided on as the most convenient and suitable, after an attempt had been made to collect it at the breathing line. Only by taking sam-

[a] Read before the Society of Arts, Boston, November 22, 1906. Abridged, by permission, from the Technology Quarterly and Proceedings of the Society of Arts, Massachusetts Institute of Technology, Boston, Mass. Vol. XX, No. 1, March, 1907, pp. 58–118.

ples near the ground was it possible to avoid attracting curious crowds of persons whose presence would have rendered the samples valueless. Tests made of air from different elevations indicated that no substantial error was made in taking samples near the pavement.

Very few samples of air were taken in the cars. Persons familiar with the conditions of crowding in the cars of the New York subway at practically all hours of the day will appreciate the inconvenience with which delicate and bulky scientific apparatus could be used among persons standing as close together as it was physically possible to stand. Furthermore, the question at issue was not whether the passengers in the cars obtained good air or not, but whether the air outside the cars was satisfactory.

The part of the road which was in operation during the period of this investigation extended from the lower end of Manhattan Island northward to Ninety-sixth street and Broadway, where it divided, one branch continuing along Broadway to One hundred and fifty-seventh street, and the other eastward and northward until it crossed under the Harlem River and reached that part of the city known as the Bronx.

Nearly all of this road was underground. There was a short, exposed portion of a few blocks covering a valley at One hundred and twenty-fifth street, and the branch to the Bronx, after crossing the Harlem, soon emerged upon an elevated structure, which it did not leave to the end of the line; but the parts of the subway which were not underground were not considered in this investigation.

The length of the road, about 21 miles, and the rather wide variety of conditions which occurred in it made it desirable to confine the investigation as far as practicable to a representative section.

There was no difficulty in selecting this section. The road between Ninety-sixth street and the Brooklyn Bridge was, in every respect, the most important. Further on in this paper it will be shown that this section was divisible into two parts, distinct differences both as to details of construction and the condition of the air being noticeable between the part north of Fifty-ninth street and that south.

Nearly all the studies recorded in this paper, except those of temperature and humidity, refer especially to the representative section between Ninety-sixth street and the bridge. In many cases, however, they have a much wider application.

The length of the section was about 6 miles. The cubic air space included was, in round figures, 26,100,000 cubic feet, including the stations.

The section was four tracks wide, excepting a piece of tunnel which ran between Forty-second street and Thirty-fourth street. Here there were two tunnels of two tracks each, running side by side, cut through the rock.

By the contract for construction we learn that it was intended, when the road was designed, that it should be easily accessible, light, dry, clean, and well ventilated. It was largely to accomplish these ends that the road was built as close to the surface of the streets as physical conditions permitted.

Much care was taken to make the subway dry. It was declared to be the " very essence of the specifications " for construction to secure a structure which should be entirely free from the inward percolation of ground or outside water.

The roof of the subway was so close to the level of the streets that it was possible for the builders to make extensive use of vault lights for illuminating the stations with natural light. Full advantage was taken of the possibilities in this direction. The area of the vault lights at some stations was so great that little artificial light was employed, excepting at night.

Incandescent lamps were the only artificial lights used except for signals.

Provisions for cleanliness.—In constructing the road, provisions for keeping the subway clean were carefully carried out at the stations. The passenger platforms were made of cement and the walls of tile, the joints and moldings being such as to permit of easy cleaning. The stairways were supplied with safety treads, which collected much street dirt, thus keeping it from entering the subway.

Provision was made in the original design for a concrete roadbed, which would have enabled the road to be kept clean between stations; but modifications in the contract, after it was let, resulted in the construction of a broken stone roadbed, from which only comparatively large particles of refuse could be removed.

The subway was ventilated through the stairways at the stations and through blow holes in the roof. Exchanges of air between the subway and streets took place chiefly by reason of the movement of trains.

The subway was about 50 feet wide and 18 feet high on the four-track section between Brooklyn Bridge and Ninety-sixth street, and the cross section of a car occupied about 14 per cent of this subway section. The trains were from 150 feet to 408 feet long.

The number of passengers in the cars varied somewhat at different hours of the day, but the cars were usually crowded. There were fifty-two seats in each car, and when the aisles and platforms were filled the total number of passengers per car ranged from about 115 to 140. The densest crowding occurred in the rush hours when people were going to and from their work and throughout the length of that portion of the subway which was selected for closest observation.

The number of cars per train, the number of trains per hour, and the speed varied at different hours. The local trains usually con-

sisted of five cars, and ran at a rate, exclusive of stops, of about 21 miles per hour. The express trains generally consisted of eight cars, and ran at a rate, exclusive of stops, of about 26 miles per hour.

The total number of passengers carried in the subway, as indicated by an official statement of the ticket sales, averaged, for the last two months of 1905, 440,000 per day. There were about twice as many passengers carried in November and December as in July.

As a train moved through the subway, air was forced ahead of it and air followed it. As a rule, a general current flowed along the track on each side of the subway in the direction of the train movement, and these currents continued even when no train was within hearing distance. The important action of a train was to put large

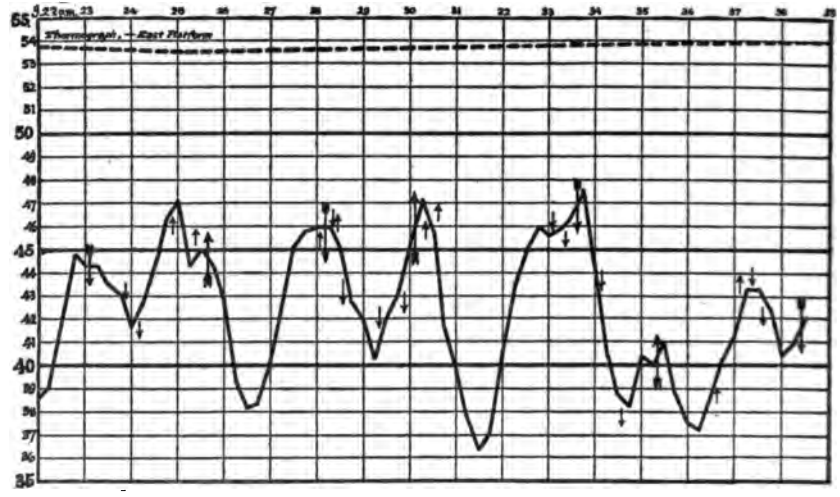

FIG. 1.—Rapid variation in temperature noted, with a ventilated thermometer and accompanying train movement. The small arrows show the movement of local, the large of express, trains in each direction. The changes in temperature were due to air currents set up by trains.

volumes of the air in motion. Where stairways or blowholes occurred and offered lines of diminished resistance, the air rushed out through them as a train approached and rushed in as the train went by.

The difference in barometric pressure necessary to set up these air currents was exceedingly slight; the effect of friction against the walls and pillars of the subway and the sides of the stairways considerable. A great part of the force with which the air currents were set in motion was generally used up in eddies about the trains. The rest was useful for ventilation.

The movement of the air depended upon the speed of the nearest train, the movement of other trains in the vicinity, the size and location of the neighboring openings to the outside air, the size of the par-

ticular cross section of the subway with reference to the sections of the moving trains, the force and direction of the wind in the streets with reference to the position of the stairways, the difference in temperature inside and outside of the subway, and other conditions.

The chemical analyses of air which were made gave data from which the frequency with which the air was renewed could have been computed had the number of passengers present at any corresponding time and part of the subway been known. Accurate information on this subject was not, however, obtainable from the Rapid Transit Commission or the operating company.

Observations with anemometers were made at a number of stations on several occasions. As a result of seventy-nine of these observations, covering, in the aggregate, two hours and thirty-five minutes, made at eight stations, it was calculated that an average of 573,000 cubic feet of air had moved in and out of one stairway per hour. This was at the rate of 9,500 cubic feet per minute.

The maximum movement of air observed was when 63,000 cubic feet passed in at one station in one minute through a single stairway. The velocity of the current on this occasion was $16\frac{1}{3}$ miles per hour.

That the air circulated freely from one station to another was shown by CO_2 analyses (to be referred to later) and by noting the time that it took an odor to pass from one station to another. Cologne of a highly concentrated grade, and in sufficient quantity to produce a distinct perfume throughout the air of a station, was used at several points and the odor noted up and down the line with the help of investigators with stop watches. Care was used that the cologne should not be transported mechanically by coming in contact with the trains in liquid form.

As a result of eight cologne experiments, it was found that the odor was carried from station to station at the average rate of 271 feet per minute, or about 3.08 miles per hour.

The ventilation of the subway bears an interesting resemblance to the ventilation of the human lungs, and it will help to understand the former if we trace some of the details of this analogy.

The ventilation of both the subway and the lungs is due to currents of air passing inward and outward as a result of changes of pressure, caused chiefly by the expansion and contraction of the enclosed space.

It is true that with the lungs the size of the enclosed space is alternately enlarged and reduced through the movement of its walls, while in the subway the size of the enclosure is increased and diminished through what is termed the piston action of the trains; but in other respects the similarity is close.

In the normal amount of air which passes out of the subway on the approach of a local train, and is replaced by an indraught of fresh air as the train draws away, we have what physiologists, in speaking of

the ventilation of the lungs, call the "tidal air." In the additional quantity which is drawn in by the express trains, we have the "complimental air," and in the excess which is forced out by express trains the "reserve or supplemental air."

These three, the tidal, complimental, and supplemental, we may term the "respiratory or ventilating capacity" of the subway.

Finally, there is an amount of air which remains in the subway and is not immediately forced into the streets by any combination of local and express trains; this we may call the "residual air."

This terminology is appropriate and convenient for general purposes, and it is suggested that it should come into use among ventilating and sanitary experts in dealing with ventilation problems of much less strictly physiological character than those to which it has hitherto been confined.

TEMPERATURE AND HUMIDITY.

From an early period in the construction of the road, an effort had been made to observe the temperature and humidity at a number of points by means of automatic, recording thermometers. Later, when the sanitary conditions were being made the subject of investigation, these records were critically examined and the observations put upon a more exact basis.

Throughout the six months' investigation with which this paper is concerned the subway was generally warmer than the streets. The only exceptions were when the outside temperature rose rapidly after a prolonged low period. This usually occurred in summer in the middle of the day, and in winter after a cold snap.

The excess of subway temperature over outside temperature increased considerably during the autumn and winter months. In the early part of July the difference between the temperature for the whole day inside and outside of the subway was less than 5°. In the latter part of September it was over 10°. In January it was at some stations about 20°. An average daily difference for a week of 30° was found at one station.

The subway grew warmer as the summer advanced. It averaged 81° through July, 1905. In the week of August 4 to 10 it was 83.4°. Thereafter it declined very gradually, until the latter part of September, when it was 76°.

In the week of September 29 to October 5 there was a slight rise to 78°, corresponding with a rise of temperature out of doors. This was followed by a more rapid decline than had occurred at any time before. Uncomfortably high temperatures were not again experienced in 1905.

During its hottest period the temperature of the subway followed the temperature of the outside air, ex[illegible] mor[illegible] and

rapid changes of the latter. This correspondence is seen to be most marked when the data for inside and outside are compared in the form of weekly and monthly averages. (See fig. 2.)

The temperature in the subway for the daytime for July and August, combining the records of these two months to form an average, was 82.4°; it was 76.8° outside; difference, 5.6°.

Highest temperatures in the summer of 1905.—The highest temperature observed in the subway during the investigation was 95°. This occurred at the Brooklyn Bridge station, July 18, 1905, at 3.50 p. m.

The hottest week was that of August 4 to 10, inclusive. The average daily temperature for the subway during this time was 83.4°; for the outside air, 78.2°; difference, 5.2°.

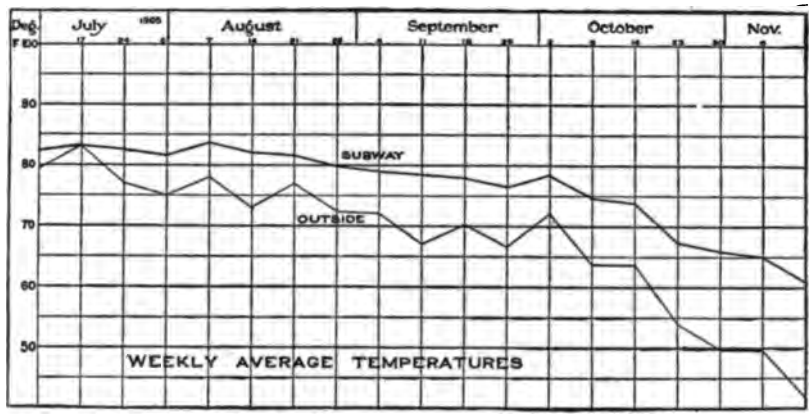

FIG. 2.—Weekly average temperatures in the subway and streets from July 10 to November 13, 1905. These averages are made up of 47,476 observations.

The maximum temperature observed in the subway during this hottest week was 88.2°; in the streets it was 88.2° at the same time.

The express stations, with the exception of Ninety-sixth street, which was exceptionally open to the outside atmosphere, were all warmer than the local stations in their vicinity.

The coolest stations were those which were most open to the street; the hottest the most closed.

The relative humidity in the subway was generally less than that out of doors, but the temperature of the dew point was higher. In other words, the actual weight of aqueous vapor present was greater in the subway than outside, but it appeared to be less in the subway than in the streets.

The humidity in the subway varied with the humidity out of doors. (See fig. 3.)

There were no fogs nor mists in the subway. A faint haze was not uncommon.

The average relative humidity for the subway for July and August was 57.5 per cent; for the outside air, 60.6 per cent; difference, 3.1 per cent.

The greatest average relative humidity occurred during the week when the average temperature was highest. During this period the relative humidity averaged 64.4 per cent.

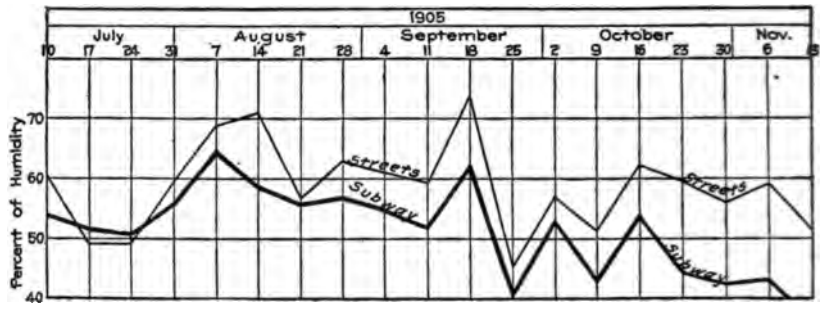

FIG. 3.—Weekly average relative humidity in the subway and streets from July 10 to November 13, 1905. These averages are made up of 47,456 observations.

CHEMICAL CONDITION OF THE AIR.

The chemical analyses of air were confined chiefly to determinations of carbon dioxide, for it was thought that no other test could give such a correct knowledge of the extent to which the air was vitiated by respiration, and none could be made on such a large scale as was wanted with so little probability of error. The method of analysis was accurate to within .03 part per 10,000.

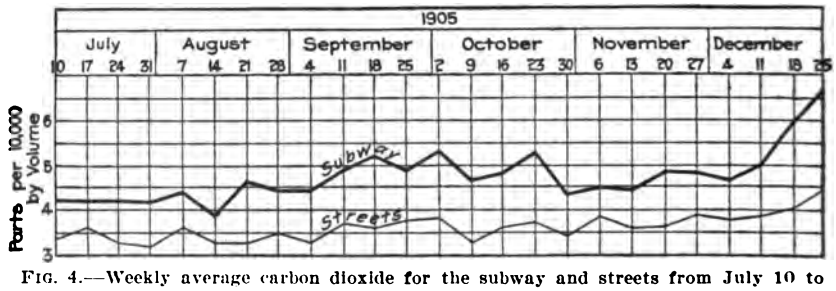

FIG. 4.—Weekly average carbon dioxide for the subway and streets from July 10 to December 25, 1905, including 1,772 determinations.

About eighty samples of air were analyzed for oxygen. The difference between the amount present in the subway and in the streets seemed so slight and uninstructive that the determinations were soon discontinued as a routine procedure.

The carbon dioxide analyses produced results from which I derived the following conclusions:

The average amount of carbon dioxide in the subway was a little larger than in the air of the streets.

The average of all results was, for the subway, 4.81 volumes per 10,000 volumes of air, and for the streets, 3.67; difference, 1.14. This difference must be regarded as very slight. (See fig. 4.)

The frequency with which the air was renewed could not be accurately calculated, for the reason that the number of passengers traveling in the subway was not known.

At no time or place was the amount of carbon dioxide large.

The greatest amount of carbon dioxide found in the subway was 8.89. This occurred in the tunnel between the Grand Central station and the Thirty-third Street station, on December 27, 1905, at 6.02 p. m. At the same time there was a block, during which trains were stalled at all points in the vicinity. At the adjoining stations of Thirty-third street and Grand Central, the carbon dioxide was higher

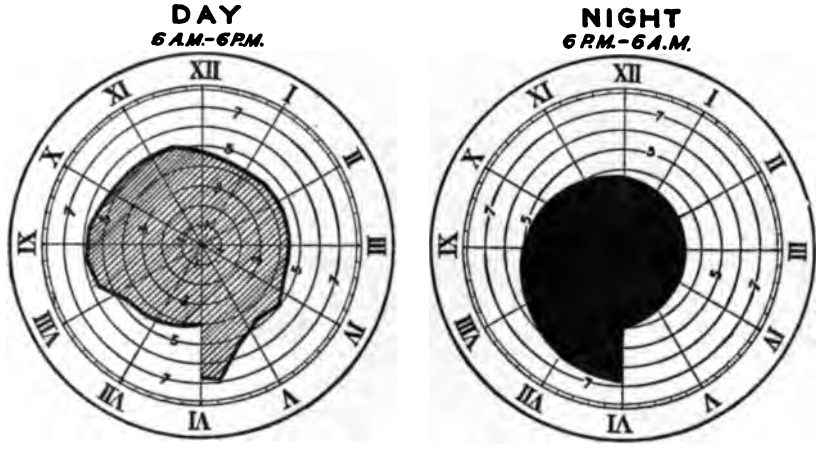

FIG. 5.—Hourly variations in the amount of carbon dioxide in the air of the subway—average of 1,244 analyses.

than usual at the same time, the amount at Thirty-third street being 7.84 and at Grand Central 7.87.

The carbon dioxide in the subway varied according to season, hour, place where the sample was collected, and other circumstances.

There was more carbon dioxide found in the autumn than in the summer or winter. It seemed likely that this was explainable largely on the ground that many more passengers were carried in autumn than in summer, and that in winter there was more wind in the streets and the subway, increasing the amount of ventilation.

The amount of carbon dioxide varied in the subway at different hours of the day. (See fig. 5.) These irregularities corresponded with the irregularities in the amount of travel which took place at different hours.

It is interesting to note that periodic changes in the amount of carbon dioxide occurred in the streets. In the streets the carbon

dioxide was highest between 5.30 and 6 p. m. and lowest between 1 and 3 a. m. The amount increased from a minimum in the early morning hours to about 9 a. m. After this there was a fall to about 1.30 p. m., followed by a rise to the highest point of the day, which occurred between 5.30 and 6 p. m. (See fig. 6.) The average range of CO_2 outside, as determined by hourly results, was 0.8 part per 10,000.

In the subway the greatest amount of carbon dioxide for the whole day also occurred between 5.30 and 6 p. m. Thereafter there was a gradual fall to the lowest point, which was reached between 3 and 4 a. m.

From this lowest point the amount increased steadily to about 9 a. m., after which it fell irregularly to between 1 and 2 p. m.

The average for the whole day agreed closely with the average between 1 and 3 p. m.

In the late afternoon there was a rapid rise to the maximum for the day, which was reached at about 5.30 p. m.

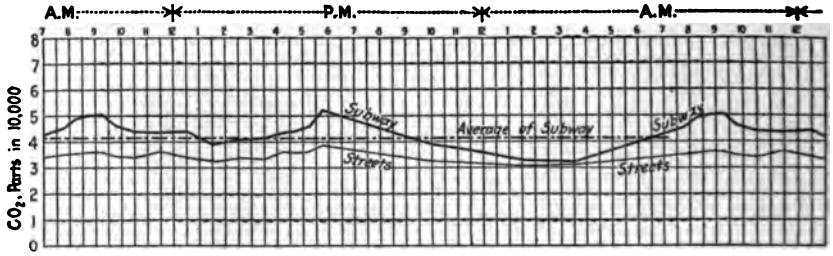

FIG. 6.—Variation in the amount of carbon dioxide in the subway and streets as determined by hourly analyses—average of 1,510 analyses.

The samples of air which were analyzed for oxygen were collected from 9.30 a. m. to 5.30 p. m., between the Brooklyn Bridge and Ninety-sixth Street stations. The average amount of oxygen found in the air of the streets was 20.71 per cent; in the subway, 20.60 per cent; difference, 0.11 per cent. The least amount found in the subway was 20.25 per cent.

BACTERIAL CONDITION OF THE AIR.

The studies concerning the micro-organisms in the subway related chiefly to the number and origin of the bacteria and molds. It was not practicable within the time and scope of the investigation to determine the various species of bacteria present, but the principal sources of many of them were investigated indirectly with fairly satisfactory results.

The bacteria were collected by allowing them to settle from the air on circular plates, or Petri dishes, 3½ inches, or about 9 cm., in

diameter, containing a standard agar culture medium (see fig. 7), and by collecting them from the air by means of sand filters.

Beside the routine estimates of the number of bacteria recovered from the air, special studies were made of the length of life of the pneumococcus in the subway, the numbers of bacteria in subway and other dusts, the action of lubricating oil upon bacteria, the kinds of molds present, and the efficiency of various commercial deodorants and germicides intended for subway use.

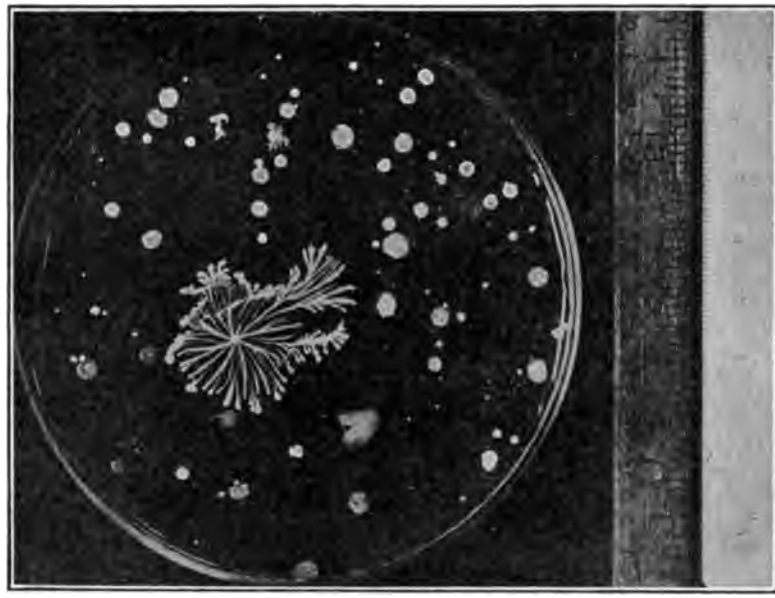

FIG. 7.—Colonies of bacteria grown on a plate exposed for fifteen minutes at the Grand Central subway station.

RESULTS.

A careful examination of the bacterial data collected in these studies, excepting the data which relate to the dust, has led me to the following conclusions:

There were, on an average, more than twice as many bacteria found in the air of the streets as in the air of the subway, excepting after rains, when fewer were found outside than inside.

The average numbers of bacteria which settled from the air in fifteen minutes, and were subsequently enumerated, were, in the subway, 500; outside, 1,157; difference, 657. (See fig. 8.)

The average number of bacteria found by filtering the air was 3,200 per cubic meter in the subway and 6,500 in the streets; difference, 3,300.

The molds recovered from the air by filters were almost always less numerous in the subway than out of doors. The maximum number

of molds found was 1,100 per cubic meter. This observation was made in the tunnel under Central Park.

The average ratio of molds to bacteria, as determined by the observations with filters, was 1 to 40 in the subway.

The wind in the streets had a decided effect upon the numbers of bacteria collected from the air, both inside and outside of the subway. The averages show that five times as many were recoverable from the air in the streets with a wind of 18 miles per hour as with a wind of 9 miles.

No attempt was made to identify the different kinds of bacteria. To have undertaken to name the species, even with a great deal more time than was available and a special corps of bacteriologists, would probably have produced little result. Nevertheless, the conclusion

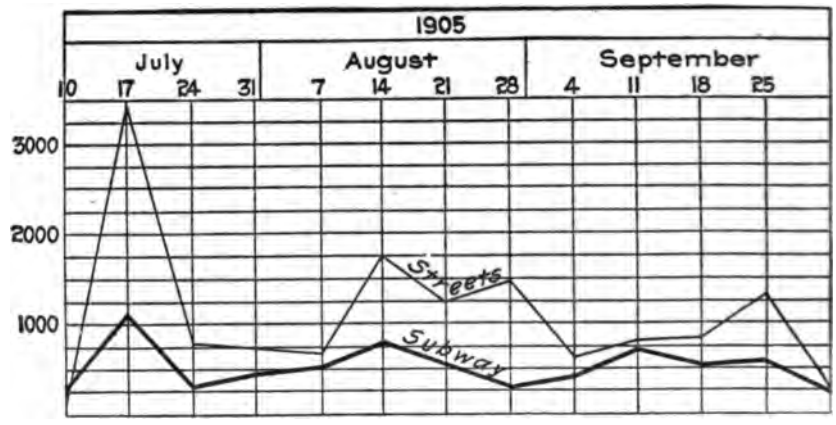

FIG. 8.—Average numbers of bacteria which subsided from the air per square foot per minute, as determined by the plate method, in the subway and streets from July 10 to October 2, 1905. The number of samples represented is 2,742.

was reached that most of the bacteria in the subway come from the streets. The principal reasons for holding this view follow:

1. The numbers of bacteria recovered from the air of the subway varied with the more decided changes in the streets.

2. The bacteria were more numerous at the subway stations near the stairways than at the remote ends of the platforms.

3. In the subway stations, the bacteria were more numerous on that side of the road toward which the wind blew than on the opposite side.

4. There were more bacteria at the arrival ends of the platforms of the stations than at the departure ends.

5. Street dirt, probably containing large numbers of bacteria, was often carried down the stairways into the subway by inrushing currents of air and by the passengers.

Although it seemed likely from these reasons that most of the bacteria in the air of the subway were derived from the streets, there was ground for concluding that some, and among them objectionable kinds, were due directly to the presence of the people. It is practically certain when great crowds are packed together, as they often were in some stations and most cars, that dangerous bacteria are, at least occasionally, transmitted from person to person. An obvious feature of this danger lies in the fact that people talk, cough, and sneeze into one another's faces at extremely short range under such circumstances.

The numbers of bacteria in the air of the subway varied with the amount of travel. They were most numerous when the trains were most numerous, and fewest when the trains were fewest.

When the trains were blocked many of the bacteria disappeared from the air. In one case the bacteria were reduced from 1,800 to 250 in about an hour in this way.

The effect of sweeping the platforms with brooms, without first taking precautions against raising dust, was noted. On one occasion the numbers of bacteria were increased by sweeping from about 5,000 to 13,000, and remained above 8,000 for at least three-quarters of an hour—the time covered by the observation.

It was not found that any harmful germs were capable of multiplying in the oil which dripped from the machinery of the cars upon the broken stone ballast and wooden ties of the roadbed.

The lubricating oil apparently removed and collected from the air large numbers of bacteria, many of which soon ceased to exist.

The pneumococcus was found capable of retaining its virulence in dried sputum in the subway for twenty-three days. This is in marked contrast to the findings of Wood, who reported that the pneumococcus was killed in four hours in sunlight.

With few exceptions, there were not so many bacteria in the air of the toilet rooms as in the rest of the subway. In some cases the numbers were much greater.

The proprietary disinfectants used in the toilet rooms had no germicidal or deodorizing value. Furthermore, they produced counter odors of a peculiarly unpleasant character.

The numbers of bacteria recovered from the dust of the subway averaged 500,000 per gram.

The largest number of bacteria found in subway dust was 2,000,000 per gram. Still greater numbers probably could have been found by selecting the specimens of dust toward this end.

For comparison with the numbers of bacteria found in dust from the subway, it is interesting to note that dust which had accumulated under similar circumstances in a Broadway theater contained 270,000

bacteria; in a new and fashionable hotel, 360,000; in a well-known Fifth Avenue church, 320,000; in the tallest office building in the city, 850,000; and in the quiet attic of a country house one hundred and fifty years old, 110,000 bacteria per gram.

Dust which had accumulated in the subway contained over twice as many molds as dust collected in outside buildings. In the dusts the ratio of bacteria to molds was 89 to 1 for the subway, and 250 to 1 elsewhere.

ODORS.

Odors were more or less prevalent at all times and at nearly all places in the subway. In some cases they were so faint as hardly to be noticeable, in others very decided.

The effects of the odors upon the passengers varied with the sensitiveness of the individual. To some persons the odors were exceedingly offensive, to others they were barely noticeable; many passengers soon became used to the odors and did not seriously object to them.

To persons unaccustomed to the subway the odors were unpleasant, and suggested that conditions existed which were injurious to health.

The odors were most apparent during hot, damp weather, at places where the greatest crowding occurred and where the least amount of ventilation took place.

Odors were far more often offensive in the cars than elsewhere, especially in the fall and winter months, when the windows were closed and the number of passengers was unusually large.

An effort was made to ascertain the main causes of the odors. It was not possible to analyze them chemically or to measure them by other means than the senses, although samples of subway dust and air, when brought to the laboratory, often smelt unmistakably of the subway. By inspections in the subway and repair shops, by examining in the laboratory a large number of solid and liquid substances taken from the subway, and by attempting to duplicate the odors in closed chambers under different conditions of temperature and humidity, some of the causes of the odors were discovered.

The following conclusions are, in my view, justified by these studies:

The stone ballast of the roadbed was responsible for part of the odor. This stone was made of broken trap rock, and its peculiarly slaty odor in the warm atmosphere of the subway was unmistakable. It could be most easily distinguished, especially at the more open stations, on damp days.

Frequently the odor of the trap was masked by other odors.

The oil used in lubricating the wheels and machinery of the cars was one of the principal causes of odor. Large quantities of this oil

were allowed to drip from the machinery upon the ballast and ties of the roadbed when the subway was first put in operation.

Samples of the oil were obtained for experiment. It was not feasible to determine by analysis its exact composition, but in other ways it was ascertained that it was composed chiefly of petroleum and fish oil.

The quantity of oil used in the subway in the first year of operation was larger than had ever been used on an equal length of road.

Much of the oil and grease was heated on the bearings, and some of it was volatilized. The car journals, motor armature bearings, and motor axle bearings were sometimes raised to a temperature of from 100° to 170° F.

That the oil was distributed through the atmosphere of the subway was fully demonstrated. It was recovered from the dust by extraction with ether to the extent of 1.18 per cent by weight of dust.

Odors were given off by the hot motors acting upon various more or less volatile substances other than oil and grease. Among these substances were the insulating material covering some of the electric wiring and the paint upon the motor cases.

Electric sparking produced the odors of ozone and nitrous oxide.

The hot brake shoes gave off a peculiar odor.

A pungent and unpleasant odor was produced by the proprietary disinfectants used in the toilet rooms. This odor was so penetrating that it was occasionally noticeable on the streets outside of the subway.

A strong and disagreeable odor was caused by an oily cement used in fastening decorative tiles in place at some of the stations. An ingredient of this cement was a cheap grade of fish oil. In order to disguise the fishy odor, creosote was freely mixed with the oil before mixing it with the cement. The result of these intermingled odors was peculiarly unpleasant. Fortunately, the odor of the cement, although very powerful at first, rapidly disappeared.

Hot boxes, of which there were a considerable number when the road was first put in operation, at times produced a persistent and suffocating odor. Wool waste was used in packing the car journals, and when this caught fire its unpleasant smell could be distinguished through the subway for a long time.

Occasionally a fuse was blown out and its odor distributed up and down the line. When a fire occurred, as happened on a few occasions, the odor of smoke persisted in the part of the subway where the fire occurred for a surprisingly long period of time. In one case the odor was distinctly noticeable to passengers, as the cars passed the spot, three months after the fire had taken place.

The odor of tobacco smoke was not uncommon at the subway stations. Rules existed against smoking in the subway, but they were

not enforced. Lighted cigars, cigarettes, and pipes were occasionally carried even into the cars.

Odors from new concrete and fresh paint were often noticed. The former was persistent, the latter transient.

Odors of human origin were sometimes present, but almost always close to people. They were most common during warm, damp weather and where there was much crowding. These odors often came from the clothing of the passengers. It was sometimes possible to learn the occupation of a workman by the odor of his clothes. Odors of coffee, garlic, bad teeth, liquor, cheese, and perfumery were some of the personal odors noticed.

The peculiar odor given off by clothing which had been hung in a kitchen was frequently noticed.

In fact, under the conditions of crowding, amounting frequently to close personal contact, it seemed that odors of practically every character connected with human existence were noticeable.

Excepting in rare instances, where ignorant employees were not kept under as strict supervision as their defective sense of decency required, the odors which permeated the general air of the subway did not point to conditions dangerous to health. Personal odors were detectible only at short range. When people are crowded so closely together that their breath and other body odors are offensive, there is always danger that disease may be transmitted from one to another.

The toilet rooms were much neglected at the time of this investigation, and often gave rise to an unpleasant local odor.

DUST.

The dust of the subway was made the subject of study because of its unpleasant features and the possibility that it might play a part in producing or aggravating respiratory diseases. Its possibilities for harm were considered to lie in its bacterial and physical composition.

The dust was examined microscopically, chemically, and bacteriologically, by a special method which was devised for determining the gross weight of dust in a measured volume of the air, and by an instrument for estimating the total number of floating particles present.

In appearance, the dust was always black and very finely powdered. It was easily distinguishable by the eye from dusts collected in the streets and in theaters, churches, office buildings, and mercantile and manufacturing establishments.

The subway dust had a peculiarly adhesive character, which caused it to attach itself securely to all surfaces, even when these were vertically placed and glazed. All parts of the subway which had not been recently cleaned and painted, or were not of a dark color, were sprinkled with this black dust when the investigation began.

The dust had a marked capacity for soiling linen and other articles of clothing. Straw hats and the light-colored garments worn by passengers of both sexes in summer were likely to be soiled by coming in contact with even small accumulations of the dust.

When examined microscopically, the dust was found to be composed of particles of many substances, conspicuous among which were fine, flat plates of iron. In fact, these iron particles could often be seen with the naked eye, glistening upon the hats and garments of persons who had been riding in the subway.

Particles 2 mm. long were on one occasion taken from a magnet which had been carried in the hand on a ride of twenty minutes in the cars. By comparison it was found that magnets hung up in the

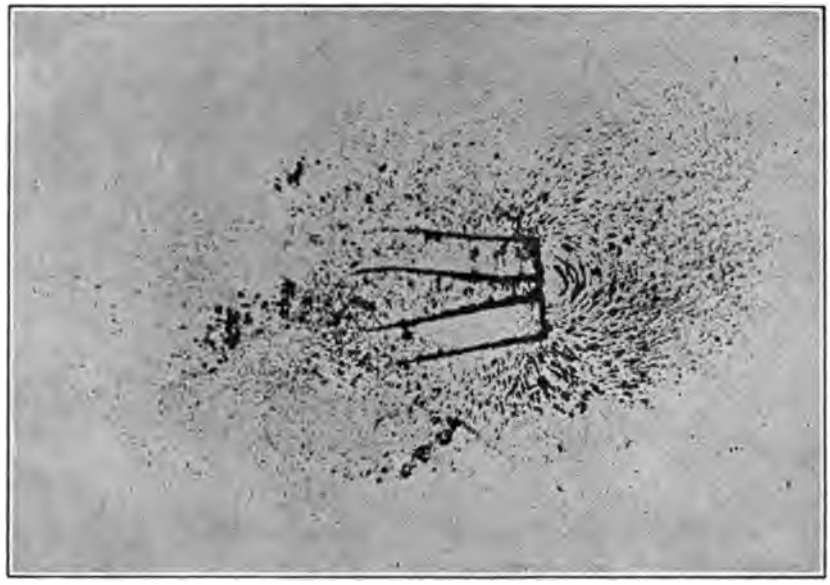

FIG. 9.—MAGNETIC FIELD FORMED BY SUBWAY DUST.

subway collected more particles of iron than magnets of the same size and strength hung up in an iron foundry or a dry grinding and polishing establishment. Fig. 9 shows a magnetic field formed by subway dust.

The size, as well as the number, of the particles depended upon the place where they were sought.

Many were so small that they floated in the air as dust. These generally escaped notice, except where beams of sunlight entered the subway or where the subway air emerged from some small opening into the sunlight in the streets, under which circumstances they glistened plainly.

Particles of subway dust, not iron, comprised bits of silica, cement, stone, fibers of wood, wool and cotton, molds, and undistinguishable fragments of refuse of many kinds.

Besides the dust which resulted from the grinding of metals, it was evident that the gradual wear and tear of many substances in the subway contributed to the dust.

Chemical composition of the dust.—The separate chemical analyses of eleven samples of accumulated dust from the subway showed the following average percentage composition: Total iron, 61.30, including 59.89 metallic iron; silica, etc., 15.58; oil, 1.18; organic matter, 21.94, as shown in fig. 10.

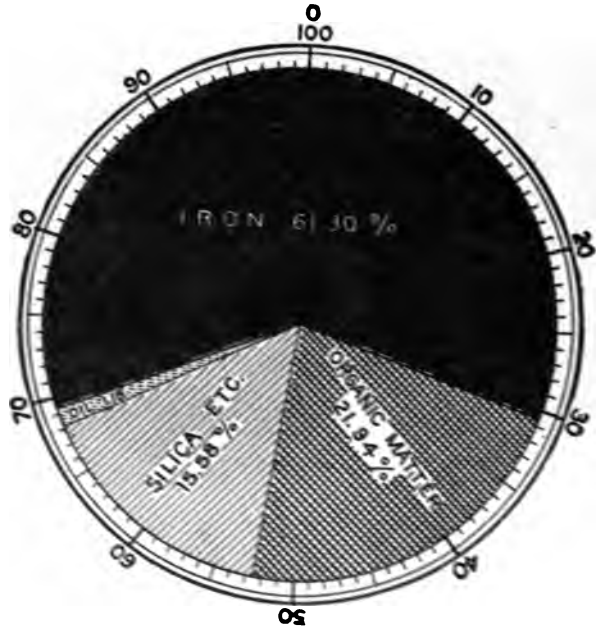

FIG. 10.—Composition of subway dust as determined by chemical analyses of eleven samples.

Origin of metallic dust.—A large part of the metallic iron came from the wear of the brake shoes upon the steel rims of the wheels of the cars.

The wear upon the brake shoes was very severe. By weighing them when they were new and after they were worn out, and determining the number used, it was calculated by the operating company that one ton of brake shoes was ground up every month for each mile of subway. The brake shoes consisted of cast iron with steel inserts.

There was also some loss to the rails and rims of the wheels and to the contact shoes which ran upon the third rail. Probably 25 tons per month would be a low estimate of the weight of iron and steel ground up in the whole subway every month.

Weight of dust in subway and street air compared.—The average weight of dust suspended in the atmosphere of the subway as found by the use of sugar filters, using all of the results, was 61.6 mg. per thousand cubic feet of air, or 2.25 mg. per cubic meter; in the streets, 52.1 mg. per thousand cubic feet, or 1.83 mg. per cubic meter; difference, 9.5 mg. The maximum amount found in the subway was 204 mg.

Twenty-three comparative tests were made to determine with particular care the weight of suspended dust per thousand cubic feet of air inside of the subway and in the streets at the same time and as near the same place as possible. These showed an excess of dust in the subway of 47 per cent over that outside. In five cases there was more dust outside, the greatest excess being 30 per cent. In the other eighteen cases the excess of subway dust over street dust ranged from 11 to 800 per cent.

Weight of dust inhaled by passengers.—The weight of dust which the average passenger inhaled in one-half hour in the subway was very slight. Assuming that 360 c. c., or 22 cubic inches, of air were taken in at each breath and that the passenger breathed eighteen times a minute, the total quantity of air which passed into the lungs in half an hour was about 6.88 cubic feet, or 6.50 cubic meters. Using the average of all results, or 61.6 mg. per thousand cubic feet, as the weight of dust suspended in the atmosphere, it appears that the average passenger took into his nose or mouth 0.42 mg. of dust in a ride of half an hour.

The amount of dust found in the air of the subway varied with a number of circumstances. More dust was found at the arrival ends than at the departure ends of the station platforms. This was probably due to the fact that the brakes were applied near the arrival ends, and to the fact that the currents of air from incoming trains helped to carry dust from those sections of the subway which lay between stations to the platforms.

The stations where the greatest weights of dust were found were express stations; there the amount of metallic dust formed by the braking of the trains was much greater than at the local stations and the travel from the streets was greatest.

The numbers of bacteria found in the accumulated dust of the subway were usually smaller than the numbers found in dust which had accumulated outside.

The average result of thirty samples of dust which had accumulated in the subway was 500,000 bacteria per gram of dust. The average obtained from six samples of dust which had accumulated under what appeared to be comparable circumstances in different buildings in New York was 600,000.

The largest number of bacteria found in a sample of subway dust was 2,000,000.

FINAL CONCLUSIONS.

A review of the results of the investigation warrants, in my opinion, the following brief statement of the most essential facts determined with respect to the quality of the air.

According to usual sanitary standards, based on chemical and bacteriological analyses, the general air of the subway was always and everywhere satisfactory. The air in the cars in winter is not included in this statement.

According to public opinion, based on the testimony of the senses, the air was everywhere unsatisfactory, especially during the summer months.

My own conclusion was that the general air, although disagreeable, was not actually harmful, except, possibly, for the presence of iron dust. The strong drafts in winter at the stations and the lack of sanitary care exercised over the subway were, however, worthy of careful consideration in this connection.

The high temperature of the subway was its most noticeably objectionable feature. Had it not been for the heat, it is probable that the other unpleasant features would have failed to arouse serious protest. The heat, as is well known, was due to the conversion of the electric power which ran the trains into friction. The amount of heat given off by the passengers was so small by comparison as to have had practically nothing to do with elevating the general temperature.

The heat was most objectionable in the mornings and evenings of summer during the hours of greatest travel and when the air outside was cooler than during the rest of the day.

The heat did not indicate that the air was vitiated or stagnant, as was popularly supposed. The subway was hot because a great deal of heat was produced in it, and stored by the materials of which the subway was built. That the heat did not escape rapidly enough for comfort was no proof that the air was not renewed often enough for health.

The carbon dioxide and oxygen analyses indicated that the products of respiration were rapidly carried away. Among the 2,200 carbon dioxide determinations, most of which were made in the subway, no sample of air was found which contained above 8.89 parts of CO_2 per ten thousand volumes, and this amount was found under circumstances which must be regarded as exceptional.

The average excess of carbon dioxide in the subway over that in the streets, 1.14 parts per ten thousand volumes, showed that the air was renewed with remarkable frequency. In the absence of a census giving the number of passengers in different par subway at dif-

ferent hours, it was impossible to calculate just how frequently the air was renewed; but from such estimates as it was possible to make it seemed not improbable that the air of the whole subway was completely renewed at least every half hour.

It is true that the renewal occurred somewhat more frequently in some parts of the subway than in others, but the exchange was always and everywhere abundant to satisfy usual sanitary requirements. We must except, of course, from this statement, the cars when closed, and other places where dense crowding occurred.

The controlling condition which regulated the extent to which the air was renewed was the freedom with which it could move in and out of the subway. The air was best where the subway was most open to the streets, and, conversely, it was least satisfactory where the subway was most inclosed. More blowholes would have greatly improved the conditions as regards heat and odor.

The movement of the trains set in motion the essential ventilating currents. This they did, first, by forcing subway air out and bringing street air in at openings; and second, by moving the air through the subway between openings.

It was fully demonstrated that there were no pockets or other places where air stagnated. Diffusion was everywhere rapid, complete, and satisfactory. I except the cars in these statements, as already indicated.

The fact that there were only about half as many bacteria found in the air of the subway as in the air of the streets under which the subway ran gave ground for the opinion that the bacteriological condition of the subway air was satisfactory, although too much reliance should not be placed upon this guide to its condition. Judgment on this point would have been more conclusive had it been possible to demonstrate that no more harmful bacteria existed in the subway than in the air outside. This was beyond the practicable possibilities of bacteriological technique.

The odors of the subway, like the heat and dust, were objectionable, apparently, chiefly because they were disagreeable. They resulted largely from the operation of the trains. They were, in my opinion, to a large extent preventable.

The sanitary significance of the characteristic black dust of the subway, containing, as it did, over 61 per cent of metallic particles, remained to be considered at the close of the investigation. At the request of the board of rapid transit commissioners, this matter is now being studied by me.

MARCELIN BERTHELOT, 1827-1907.

MARCELIN BERTHELOT.[a]

By Camille Matignon,

Professor of Mineral Chemistry at the Collège de France; former Assistant Professor to Berthelot at the Collège de France.

The illustrious scholar to whom all France has paid a last solemn tribute held an extraordinary rank in the science of the nineteenth century. What he accomplished was tremendous, almost superhuman. No other man can grasp it in its entirety, for in order to comprehend it in detail one would need to have an encyclopædic knowledge such as no one in this day possesses. The scholars of the whole world bowed before this grand intellect, unanimously recognized as one of the broadest of its time. This intellect, moreover, was powerfully aided by a memory no less widely famed. It was by uniting with these natural gifts, obstinate and incessant, systematic endeavor, that Berthelot was able to build up an immense life work in which is shown the universal scope of his knowledge. A man of letters, a philosopher, an historian, there was no subject with which he was not familiar; he was well and accurately informed on all topics.

Pierre Eugène Marcelin Berthelot was born in Paris, October 28, 1827, in a house on the place de Grèves, now the place de l'Hôtel de Ville. He studied at the Lycée Henri IV, and showed from the start remarkable aptitude in the most varied directions. Fouqué, in recalling at the fiftieth anniversary of his scientific career the old fellowship of the Lycée that brought him close to Berthelot, added: "Even at that time you felt the lofty position in the science of the future which awaited you. Your professors, and even your fellow-students, were alike conscious of it, and, more than anyone else, I had faith in you." In 1846 Berthelot won the honor prize in philosophy at the Concours général. He devoted himself henceforth to the study of the sciences without passing through any school. He was selected as Balard's assistant in the Collège de France in January, 1851, and for nine years he filled this humble office with its annual allowance of 500 francs. During this period, in April, 1854, he

[a] Translated, by permission, from Revue Générale des Sciences pures et appliquées. Paris, 18th year, No. 9, May 15, 1907.

earned the degree of doctor of sciences with a masterly thesis on the "Reproduction des corps gras naturels."

On December 20, 1859, he left the Collège de France for l'École de Pharmacie, where he had been chosen professor of organic chemistry. The following year he brought together his researches on synthetic chemistry in two important volumes entitled "Chimie organique fondée sur la synthèse." The Academy of Sciences, for his assembled works, awarded him the Jecker prize. Berthelot, at 33 years of age, was known by name to chemists throughout the world, and his reputation had penetrated even into the Parisian salons, as is evident from letters written in 1860 and 1861 by Madame Didier to Madame Edgar Quinet: "I must not forget to have you meet a very learned scholar named M. Berthelot. They swear by him alone in the rue de l'Ouest [at Michelet's]. Madame Michelet told me 'that he would go down to posterity,' and that he would not rest satisfied with mere genius. He is, besides, full of life and a charming fellow to be with. She drew me the picture of an accomplished man; I am curious about this wonder. I must make his acquaintance and tell you my impressions of him." (October 26, 1860.) After having received him she wrote (January 19, 1861): "He seemed shy; he has a very sweet and interesting countenance. I greatly enjoyed the conversation of M. Berthelot. If I have one regret it is in not being able to follow him in the field of science; he has made great discoveries in chemistry and has published two volumes that are beyond me; I should not be able even to understand their language. But they say that the synopsis of the book is obtainable and it gives the conclusions of all of his works. I shall do my best to get an idea of it. Finally, there is nothing he does not know something about; he has had a thorough literary education."

At the initiative of Balard, a certain number of professors of the Collège de France and chemists of the Institut requested of the public officials the establishment of a chair of organic chemistry in the Collège de France, in order to allow Berthelot to develop his ideas. The request was favorably received by M. Duruy, minister of public instruction, and the chair was created August 8, 1865. Berthelot then gave up the École de Pharmacie for the Collège de France, which he was destined never to leave.

A member of the Academy of Medicine in February, 1863, he did not enter the Academy of Sciences until March 3, 1873, at the age of 46 years, in the section of physics, taking the place of Duhamel. He developed at this time a whole system of calorimetric methods. He was not only a chemist of the first class, but likewise an eminent physicist, as was recognized by the Institut in giving him the first vacant place in the section of physics. Most of the foreign scientific societies and academies sanctioned Berthelot's fame by admitting him

to their own membership. He was elected successively to the Royal Society of London, the Society of Physics of Geneva, the Society of Naturalists of Moscow, and the academies of St. Petersburg, Stockholm, Dublin, Copenhagen, Munich, Turin, Amsterdam, Hungary, Boston, Lisbon, Vienna, Berlin, etc.

Designated chevalier of the Legion of Honor August 13, 1861, he ran rapidly through the whole hierarchy until by the time of the fiftieth anniversary of the beginning of his scientific career the Government of the Republic had decreed to him the highest reward it gives in decorating him with the Grand-Croix.

The interest that Berthelot brought to bear on the reorganization of our method of education led him to the general inspection of higher educational affairs in 1876; to the permanent section of public instruction, of which he was vice-president; to the École des Hautes Études, of which he was president for the section of physical sciences. Head of the scientific committee for the defense of Paris in 1870, he was named member of the consultation committee on powders and saltpeters in 1876 and president of the commission on explosive substances in 1878. Elected perpetual senator in 1881, he improved the opportunity by pleading on numerous occasions the cause of higher education and of scientific research. In 1886 he became minister of public instruction in the Goblet cabinet and was called later by M. Léon Bourgeois to the quai d'Orsay.

Berthelot succeeded Joseph Bertrand in the Académie Française, and was received there by Lemaître.

I do not pretend in the few pages at my disposal to estimate as it deserves the work of this teacher; I shall content myself with sketching merely its principal features.

Berthelot not only transformed and broadened the domain of chemistry, but at the same time he caused this science to progress by the side of the exact sciences.

Before Berthelot most chemists considered the substances which form in living organisms as impossible of reproduction in the laboratory from their constituent elements—carbon, oxygen, hydrogen, and nitrogen—by the sole play of chemical affinities. "In organic nature," wrote Berzelius in 1849, "elements appear to obey laws entirely different from the laws of inorganic nature." A mysterious force, the vital force, is judged indispensable to their elaboration. The chemist can only destroy them, separate them with the aid of appropriate reagents, and take from them certain new substances, isolated stones in the complex edifice. His rôle is therefore extremely limited, since in the field of organic compounds he has at his disposal, as objects of study, only the immediate principles elaborated by animals and vegetable growths. Berthelot took up the separated products and tried step by step to put them together again to con-

struct the initial edifice. It was thus that, in a really masterly achievement, he reconstructed fats, oils, and butters out of the glycerine and the acids derived from these fatty substances. The barrier which separated the reactions of the laboratory from the reactions of living organisms disappeared from this time on and the identity of biological and physico-chemical forces was thereupon established. The significance of such a demonstration may be readily understood.

This was not all. It was at this time that the creative power of the chemist began to be manifested. As soon as Berthelot had discovered how to reproduce a fatty substance, stearine, for example, he had by the generalization of the process found the method of reproducing an infinite number of new fatty substances. Thus, while most of the animal or vegetable fats are formed essentially by the mixture of three or four well-defined chemical substances, the only ones found in nature, the chemist can make from them in his laboratory as large a number as he pleases. "The synthesis of neutral fats," said Berthelot in 1860, "permits not only the formation of some natural fats already known, but it still further permits one to foresee the formation of innumerable analogous fats, which it will be easy hereafter to produce in their entirety by virtue of the general law that governs their composition." The domain of chemistry therefore becomes unlimited. The chemist himself, by synthesis, creates the object of his investigation and in the thousands of new substances that are produced each year in the laboratories of the world, he distinguishes those whose properties can be used in the arts, in industry, in medicine, etc.

The synthesis of fatty substances was only a partial synthesis; glycerine and the fatty generating acids were themselves produced from fats originally divided in two. In imitation of nature it was necessary to try to produce organic matters out of mineral substances. Taking carbon in the form of carbonic oxide, Berthelot combined this gas with potash and produced potassium formate. The barium formate, heated, lost methane, which by pyrogenation was able to give acetylene, ethylene, and ethane. From these carburets thus formed, Berthelot passed to the corresponding alcohols, methyl, ethyl, and their very varied derivatives.

It is not, however, under the form of carbonic oxide that charcoal enters into plants; these build up the molecules of fatty matters, the hydrates of carbon necessary to their growth, with anhydrous carbon and water. Berthelot tried in vain to generate a primary carburet out of these two substances, so he replaced them with substances whose functions were most closely related to them, sulphuret of carbon and sulphuric acid; then in making both of these pass over copper, he obtained methane. By substituting iron for copper he obtained the same reaction from sulphuret of carbon and water.

In his work " Chimie organique fondée sur la synthèse," Berthelot published the collective results of his researches and at the same time he explained the methods that should be followed in solving the synthetic problem in the series not then studied. He presented a general view of organic products, and in order to classify them, introduced the theory of function. He had previously, in the case of glycerine, shown that the molecule of that substance possesses three times the alcoholic function and likewise introduced the idea of polyatomic alcohols and polyalcohols.

Berthelot employed electric energy in its most varied forms to bring about the combination or to destroy the composition of substances. The electric arc enabled him to effect the simplest, the most unexpected, and the most fertile of organic syntheses, that of acetylene. An arc flashing in an atmosphere of hydrogen partially transformed this hydrogen into acetylene, for the carbonic vapor which constituted the arc through its high temperature of 3,500 degrees united directly with the gaseous element. Carburetted hydrogen, stable at the highest temperature reached, became, on the contrary, unstable at about its ordinary temperature; it only had to be compressed to above two atmospheres for it to decompose with an explosion, under the influence of a spark, into its two elements, carbon and hydrogen. If, on the contrary, it is heated gradually toward 400 degrees, the same acetylene returns to its stable form, carbon and hydrogen, passing through a series of intermediate terms, benzol, toluol, naphthalene, anthracene, etc., carburets poorer and poorer in hydrogen, the limit of which will be charcoal. These new carburets constitute the starting point in preparing coloring matters, perfumes, substitutes for sugar, new explosives, etc. It is possible to combine again with acetylene, by the aid of simple reactions, ethylene, ethane, oxalic and acetic acids, alcohol, etc. Thus by heating the carburet with its hydrogen, ethylene is generated, capable of fixing water in the presence of sulphuric acid to form alcohol. The entire synthesis of this immediate threefold principle is thus realized from its three constituent elements, carbon, oxygen, and hydrogen.

The electric spark is likewise useful in synthetic chemistry. For example, the sparks produce hydrocyanic acid when nitrogen is placed in the presence of acetylene, or, generally, of any hydrocarbon vapor whatever.

The electric current passing into a conducting solution permits the obtaining of products of oxidation at the anode and products of reduction at the cathode. The sulphuric solution itself peroxidizes in giving a new substance, persulphuric acid, the existence of which was at first doubted by several chemists who had not experimented, until persulphates became industrial products.

Berthelot, moreover, made an exhaustive study of all the secondary chemical reactions which were produced at or near the electrodes. Upon these complex questions no chemist had so comprehensive a knowledge founded on experiment. Thus we may understand the skepticism with which he received all mathematical theories overlooking these secondary reactions.

It was above all through the electric current that Berthelot obtained the most delicate syntheses. He showed that this current constituted the form of energy the most active and the most effective for securing the combination of substances. By its aid he was enabled to unite iodine with oxygen, to produce sulphuric anhydride from sulphurous gas and oxygen, to effect the absorption of nitrogen in considerable quantities by sulphuret of carbon, benzol, etc. Everyone still recalls the discovery of argon by Lord Rayleigh and Ramsay, who, after a number of years of trials of different sorts, were unsuccessful in obtaining a combination with this new gas. These scholars sent Berthelot several cubic centimeters of argon, and eight days after the eminent chemist announced to the Academy of Sciences that he had succeeded in uniting argon with sulphuret of carbon by means of the electric current. The small quantity of resinous matter obtained under these conditions, when sufficiently heated, in decomposing, regenerated argon with its initial properties.

The contemporaries of Berthelot also did their share in developing chemical synthesis. It is sufficient to recall in particular his rival, Wurtz, to whose credit stand very important experiments on the synthesis of compound ammonias, of carburets of hydrogen, and of glycols. "It is with respect to the synthesis of glycols," wrote Berthelot in 1884, "that a productive rivalry has arisen between us, in which each of us has developed the various resources of a nature as different from that of the other in its point of view as in its operations. Works without number have sprung from these theories and in thirty years have transformed organic chemistry. Wurtz played a prominent part in this transformation."

Convinced of the unity of natural forces, Berthelot tried to adapt the laws of chemical transformations to the laws of mechanics. He devoted himself to developing a new science, thermochemistry, from which was derived chemical mechanics. Lavoisier and Laplace, Hess, Favre and Silbermann had already succeeded in making several calorimetric measurements, but the principle of equivalents in the order of chemical reactions was a new idea which was to be established with precision by the researches of Berthelot. At this time Regnault had completed his numerous calorimetric experiments and had created for this division of physics an accuracy heretofore unknown. Berthelot perfected this accuracy through a more complex apparatus by superimposing in a certain way all the principal appa-

ratus accessory contrivances either to eliminate or to measure the different causes of error. Berthelot, however, secured accuracy by more simple methods. The experimental technique which he worked out from beginning to end for measuring different calorific factors is an admirable accomplishment, which would suffice alone to make a physicist illustrious. Although I have had occasion to initiate a large number of French and other scholars into the calorimetric methods of Berthelot, I have never once done it without noting after a first experiment their astonishment and their admiration for methods so simple and accurate. These methods were afterwards to attain perfection in the use of the calorimetric bomb.

Altogether, Berthelot's accomplishments in thermochemistry are marvelous. Their consequences extend into all domains of science. Engineers, experimenters, and theorists are continually using his calorimetric data.

In theory, Berthelot shows that the amount of heat is the principal factor upon which depend the conditions of composition or decomposition of substances; but the mass heat of reaction is connected with these conditions by an extremely complicated relationship. Berthelot tried to disengege from this mass heat all the calories connected with reversible phenomena and obtained a quantity, "chemical heat," which approaches the heat not compensated for in the reaction. From 1865 Berthelot worked without interruption to establish and render exact the different terms for expressing chemical heat.

This chemical heat, especially in solutions, is not always easily calculated, and so in the secondary schools they have let stand the old rule of maximum work, which in many cases can give an exact idea of the process of reaction.

The study of electrical piles, which forms, with the working out of reactions in advance, one and the same problem, took part of Berthelot's time. As I said above, he studied very thoroughly all the secondary phenomena which occurred in connection with it in such a way as to separate from the chemical mass energy all these secondary forms of energy and to try to give, if possible, an experimental interpretation of the differences between the voltaic and chemical energies. M. Berthelot has frequently called attention to the importance of these secondary reactions often neglected by the theorists. For this reason the pupils of Helmholtz could verify the accuracy of the relation between voltaic and chemical energy only by measuring the chemical energy directly on the calorimeter, as Jahn did, and not, like Brauner, by calculating it from the fundamental chemical reaction occurring in the pile.

Moreover, in a general way, the study of the thermo-chemistry of reactions forced Berthelot to go into their slightest details, and, with

his talent for generalizing, he knew how to draw observations of a general application. It is thus that the idea of preliminary work, necessary for bringing about reactions, corresponds in the language of this time to an elevation of temperature necessary to overcome chemical resistance. He showed likewise that it is not the reactions producing the most stable system that are found, but unstable, intermediary systems. The principle of the appearance of the unstable forms before the stable forms is found again here, a principle which has been quite accurately established in these later years. Moreover, all the modern physico-chemists have drawn from the numerous thermo-chemical documents accumulated by Berthelot, and some of them have even at times reproduced his researches, but in a language corresponding to the physico-chemistry of these later years.

I am convinced for my part that it is particularly through thermochemistry that Berthelot acquired that truly extraordinary understanding of chemical phenomena by which he seemed almost to dominate and command them.

Thermo-chemistry was destined to lead Berthelot to the study of explosives. His position as president of the commission of scholars organized by those in command of the national defense during the siege of Paris had given him an opportunity to become initiated into the knowledge of these products. The various tasks that he accomplished in this field either alone or in collaboration with members of the commission on powders and saltpeters, have been brought together in great part in his treatise "Sur la force des matières explosibles d'après la Thermochimie." I should like to speak here simply of his "studies of genius," to use the expression of Nernst, on the explosive wave. In a mixture of oxygen and hydrogen, for example, the combination propagates itself in the form of a wave all the factors of which can be defined in advance when the properties of the exploding mixture are known. The surface of this wave, which is the seat of the combination, propagates itself with a speed much greater than that of sound, 2,800 meters in the case of oxygen and hydrogen, so that the influence of the cooling of the surfaces has no time to become effective. Besides, the speed itself is constant and independent of the nature of the tube which contains the mixture. The surface of the wave is at an extremely high temperature and exerts a strong pressure in its passage, a pressure which may easily be registered by placing pressure gauges in the path of the wave.

The explosive wave has been the means of realizing the highest temperatures (4,000 degrees), but the products of combustion remain at this temperature for only a very short time. Berthelot and Vieille, in some extremely remarkable experiments, have used the explosive wave for furnishing quantitative evidence on the properties of gases at temperatures as high as 4,000 degrees. [illegible] the [illegible]

results which follow from this I may call special attention to the curious fact that nitrogen, oxygen, and oxide of carbon, up to 4,000 degrees, have identical molecular specific heats, which tends to prove that the molecule is not dissociated at this high temperature during the very short period of heating. Theoretical studies on explosives, on the speed of explosions, were to lead to the discovery of smokeless powder by M. Vieille, the pupil and collaborator of Berthelot. This was for some time to give superiority to our armament.

In collaboration with Péan de Saint Gilles, Berthelot, in 1862, in a celebrated memoir, defined equilibrium, and at the same time showed, by a full series of reactions methodically worked out, the rôle of time in chemical phenomena. He endeavored to translate into mathematical formulæ the results of his experiments. He introduced the idea of active masses, and established a relation which, slightly modified, was to lead Guldberg and Waage, the following year, as they themselves acknowledged, to the establishment of the law of mass action. For his study on etherification the name of Berthelot deserves to be inscribed by the side of those of Saint-Claire Deville and of Raoult, among the creators of physico-chemistry.

By reason of his studies of synthesis, the rôle of nitrogen in the organic world always interested Berthelot. Some years ago this element was considered as an inert body incapable of entering in reaction and yet it is indispensable to the life of animals and plants. By what process does inorganic nitrogen pass into the state of organic nitrogen? The problem is to-day in great measure solved, thanks particularly to Berthelot's experiments.

Under the influence of electrical actions, spark or current, the nitrogen and oxygen of the air enter into combination to form, first of all, oxide of nitrogen, and then, by secondary reaction, nitrous vapors. Likewise, all active combustion, like that of charcoal, for example, quickens the combination of quantities of nitrogen and oxygen. The difference of electrical potential between two strata of air of unequal levels may be employed to effect the absorption of nitrogen by the most varied bodies. By exact quantitative experiments Berthelot showed that exterior electrical actions, storms, differences of potential, and the combustions of charcoal, going on year after year in the world, are insufficient to calculate the total quantity of nitrogen necessary for the development of plants. Other causes must be found. For this reason Berthelot devoted himself to the study of the sun. He showed that the earth was enriched in nitrogen under the influence of the tiny particles that swarm here. The organic world was no longer considered inert; it became a living entity in which a race of the tiniest midgets work to introduce the elementary nitrogen of the air into the cycle of organic reactions.

The ideas of the professor were from the first warmly opposed, but soon Hellriegel and Wilfarth, Schlœsing and Laurent, Winogradski, brought in from every side important contributions to the question of the absorption of nitrogen and demonstrated in a startling manner the truth of the ideas put forth by Berthelot.

This, moreover, was not the only occasion upon which Berthelot was actively disputed by opposing scholars. A posthumous memoir of Claude Bernard towards 1878 was the text of a most scholarly and most earnest scientific discussion between Berthelot and Pasteur. The latter held, on the basis of experiments, that the fermentation of glucose absolutely demanded the presence of leaven or barm of beer, while, according to Berthelot, the transformation of glucose into alcohol could take place through the intermediary of a ferment that was not living, of a diastase emitted by the yeast itself. The two scholars maintained their positions without reaching a common conclusion. Twenty years afterwards a German scholar, Buchner, demonstrated that yeast, sufficiently compressed, furnished a liquid without trace of living cells and capable of continuing for some time the fermentation of sugared juices. Berthelot's instinct of genius had surmounted Pasteur's experimental skill.

Having acquired a knowledge of the ancient languages, Berthelot was exceptionally well fitted to study the history of chemistry in early times. In the " Origines de l'Alchimie " he shows that alchemy was founded on a doctrine of philosophy, that of the sameness of matter molded as if formed of four elements. Its practice rested upon the actual experiments performed by the Greco-Egyptian gold and silver smiths and metallurgists. This the author indisputably established by the comparative study of a papyrus found in Thebes and some receipts of the pseudo-Democritus, in a second work entitled " Introduction à l'étude de la chimie des anciens et du moyen-age."

Berthelot was led in this connection to publish the Greek, Syriac, and Arabic alchemic texts, which up to this time had remained unpublished, with the collaboration of distinguished linguists—Messrs. Rouelle for the Greek, Rubens Duval for the Syriac, and Houdas for the Arabic. Thus was again built up an entire branch of the science of the early times, theretofore almost unknown. Furthermore he pursued his studies up to the fourteenth century, in order to ascertain by what means the science of alchemy had penetrated into the Occident. He found that these means were two: First, by the handing down of the arts and industries which had up to that time been almost completely ignored and which nevertheless had subsisted continuously since the fall of the Roman Empire, and second, by the Syriac translations of the Greek alchemists, equally ignored, which were the

sources of Arabic works. These latter were translated into Latin in the twelfth and thirteenth centuries.

Profoundly patriotic, Berthelot always considered it the duty of every scholar to place at the disposal of his country the results of his experience and of his learning. He never refused his services, when asked in the name of public interest, in any of the most varied directions, especially in matters relating to industry or to the public defense, public instruction, or general governmental policy. He was attached to all the technical commissions connected with the several government departments and applied to the solution of the problems presented all the talents employed in work in his own laboratory. This multiple activity of Berthelot furnished occasion for various articles or discourses, combined in four volumes: "Science et philosophie," "Science et morale," "Science et education," "Science et libre pensée."

Like all creators, Berthelot had a powerful faith, a faith which served him as director and guide both in his private and public life, faith in science and his methods. For Berthelot science dominated everything; it alone rendered definite services, and its domain was not restricted to the study of positive facts. Material progress due to science was the least important product of his work. Science included a higher and broader field, that of the ethical or spiritual and the social world.

In his letter to Renan on the ideal science and the positive science, after having explained in a masterly way, by a concrete example, how positive science proceeds in establishing facts and in attaching one to another by immediate relations, Berthelot extended the same method to the study of the domain outside the material world: "In the domain outside the material world, as in the material order of things, it is necessary at the start to establish the facts and to control them by observation, then to marshal them by constantly bringing to bear this same observation. All reasoning which tends to deduce them a priori from some abstract axiom is chimerical. It is the observation of the phenomena of the world outside the material, revealed either by psychology or by history and political economy, it is the study of their relations gradually generalized and at each step verified, that serves as a basis for a scientific understanding of human nature. The method by which each day are solved the problems of the material and industrial world is the only method by which can be solved and will be solved sooner or later the fundamental problems relative to the organization of society."

Berthelot, moreover, recognized that truth could not be attained with such a degree of certainty in the ideal science as in positive science. "It is in a way like a building hidden behind a cloud, of

which only some outlines are visible." The farther up you go in the order of consequences, the farther away you get from real observations and the more does certainty, or rather probability, diminish. A system is true not in proportion to the logic of its reasoning, but to the sum of positive facts introduced into it.

It is to these philosophical conceptions that may be attributed to a certain extent Berthelot's opposition to constitutional formulæ. A slave to facts, he would not admit these systematized signs to which some went so far as to attach an objective reality. "The symbols of chemistry present in this respect some strange allurements by the algebraic ease of their combinations and by the tendencies of the human mind. They naturally lead to the substitution, in the place of a direct conception of things, never absolutely determined, the more simple and apparently more comprehensive view of their representative signs. It would be a strange misconception of the philosophy of the natural and experimental sciences to attribute to such mere machinery for working a fundamental importance. In fact, in the study of the sciences, all depends on the discovery of general facts and of the laws that bind them one to another." Berthelot saw in these formulæ only a chemical language, and it meant no more to him than that the facts could be translated into one or another language.

I may be permitted to recall that on reaching the college laboratory at the close of a lecture, when Berthelot had explained his ideas on notations and chemical formulæ, I respectfully suggested to him that it would be more logical for him to use a language adopted by the majority of chemists. It was following this conversation that I presented to the Academy of Sciences the first work from the laboratory of Berthelot with atomic formulæ. Some time after, in a work performed in collaboration with my teacher, on the chlorine derivatives Berthelot definitely gave up notation in equivalents for atomic notation (1890).

Berthelot, at least at the time that I knew him, attached only a secondary importance to theories. This, moreover, is a trait common to nearly all learned men who have pursued a long scientific career. They have seen so many systems rise and fall that they arrive in the end at skepticism. I presented to him one day a short paper containing some theoretical ideas to which I attached some degree of importance and I carried it to him proud of my theoretical explanation of the facts observed. Glancing rapidly over my paper, Berthelot seized a pencil and quickly crossed out all that part on which I expected to be complimented. I was still a beginner, and notwithstanding all the admiration that Berthelot commanded from those about him, I confess that I consoled myself for my disappointment by considering the act as that of a scholar grown too old. This little incident springs to my mind whenever I come across an old

memoir from which I have to draw any references and find the facts swamped in the theories of the period, to-day of such mediocre value. I am irritated at the author who makes me lose time in this way, and I understand fully the justice of Berthelot's action.

It is, moreover, a characteristic of youth, ignorant, inexperienced, and presumptuous, to hold decided opinions on everything and not to acquiesce on many points in the opinions of experienced persons and authorities. Age cures this fault quickly, but the memory of it comes back all the stronger when we find it again in succeeding generations.

Berthelot leaves a number of French and foreign pupils, many of whom are among those who most honor the chemical profession. To speak only of the oldest ones, I may mention the following: Jungfleisch, his collaborator in his "Traité de chimie organique" and in his researches on the coefficient of distribution, of which Nernst more recently published a valuable generalization; Barbier, who gave proof of great experimental ability in assisting the professor in delicate researches on the reductive properties of hydriodic acid; Sabatier, the learned teacher, well known for his works, already classic, on catalyzers of hydrogen gas; André, Berthelot's devoted collaborator in his researches on organic chemistry; Joannis, whose works on soda ammonium constitute good experimental models; de Forcrand, the distinguished director of the chemical institute of Montpellier, whose thermic data form a table of figures of undisputed accuracy; Guntz, who had the honor of separating barium and strontium in a pure state and of discovering subsalts of silver; Recoura, whose thesis was one of the most remarkable ever presented before the Faculty of Sciences of Paris, etc. In other countries a number of Berthelot's pupils teach in universities: Louguinine, Croustschoff, Ossipoff, Timoféieff, Werner, etc., in Russia; A. Werner in Switzerland; Fogh in Denmark; Hartog in England; Bredig in Germany; Paul Henry in Belgium, etc.

Berthelot's activity never waned a single instant. Last year he published a very extensive volume on the analysis of gases. He wrote out before his death a fifth volume on organic chemistry. At the same time he kept up his laboratory researches, which, by the way, were uninterrupted for fifty-five years. Berthelot could, like Hoffmann or Bæyer, have realized a considerable fortune, but he never took out a patent nor derived any material profit from his discoveries. Offers made by groups of financiers to turn into money the results of his researches were in every case declined.

Very sparing of his time, it was not always easy to hold a desired conversation with him. In order not to rob him of his leisure moments, it was best to meet him coming out of his laboratory, toward noon, and accompany him from the Collège de France to the Insti-

tut. How many times have we thus walked together down the rue de l'École de Médécin and the rue Mazarin while he chatted with me on the results of his researches or explained to me his ideas on the latest sensational discovery! But it was principally at the station de Chimie végétale de Bellevue-Meudon, where he came each year in April or May and installed himself and his family, that he willingly received his pupils on Sunday mornings. Thus, during his last sojourn at Meudon, I was chatting with him one October morning just before his return to Paris. Very busy with his researches on radioactivity, he showed me all the specimens of quartz he had colored in violet under the influence of radium, thus producing for the first time the synthesis of the amethyst. Then we passed to an examination of experiments he was conducting, of which he was destined never to know the results. Small glass tubes filled with different substances had for several days been ranged about a central tube containing a piece of radium. No transformation was yet apparent, but he was awaiting some interesting modifications by the time he should return the following spring, if, however, he added, he were still alive.

Berthelot's conversation was never trivial; his phrases were always correct, accurate, and simple, as those of a scholar and thinker should be. He gave immediately the impression of a superior man. He was, moreover, a man of delicate temperament. "There never was between us," said Renan, "I will not say a moral relaxation, but a plain vulgarity. We always acted toward one another as toward a lady we respect."

It was a genuine treat to listen to him at the private receptions presided over with such distinction by Madame Berthelot. He would then lay aside his thoughts of science to devote himself entirely to the interests of his wife and his friends. The Goncourts have described in their "Journal" the dinners at the home of Magny, where Berthelot was listened to with keen interest by everyone. "Renan," says Goncourt, "followed the trend of his thoughts without failing, and I am certain that many of the ideas afterwards uttered by the philosopher in his volumes were collected in the course of conversations with the chemist." Berthelot had, in fact, a powerful influence on the greatest minds of his time. Both Renan and Taine had a deep admiration for the learned man. It would be interesting some day to say more about the share of collaboration in Renan's work that can be traced back to the man of science.

Berthelot had six children—four sons and two daughters. He had the misfortune to lose one of his daughters, and more recently a grandson, who was tragically killed in an accident on the chemin de fer du Nord. "No loss," he wrote, "can be compared to the loss of a child who has grown up under the eyes of its parents, surrounded

and sustained by their love, and who is taken away in the flower of its youth, leaving in the depths of the hearts of its near relatives an inconsolable grief."

The dramatic death of the great man of science was a startling proof of the deep love that bound him to his wife.[a] There was between these two souls such a close union, such mutual adaptation, that their existence made a veritable "symbiose." When we saw him come to the laboratory in those last days, his appearance told us of the condition of health of Madame Berthelot. Pale and worn during the critical periods, he walked with a step more alert during the periods of improvement. We knew that the days of her illness were numbered and we had no doubt but that her death would shortly be followed by that of her husband. Their mutual affection was even deeper than we supposed it to be, for Berthelot was unable to survive his worthy companion.

In all the realms where the activity of a human being could be exercised, Berthelot had performed his whole duty. He was a scholar, a citizen, a husband, a father, a teacher, without an equal.

It would seem that such a fine nature should never encounter difficulties in its career. But this would be attributing to men a rapidity and accuracy of judgment to which they are hardly accustomed. Two months ago I confided to him some personal troubles. He placed himself, as always, at my disposal to help me overcome them.

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[a] Berthelot died at Paris, March 18, 1907, in the Palais de l'Institut, very shortly after his wife had drawn her last breath. For several years Mme. Berthelot had suffered from a serious heart trouble which left small hope of her recovery. Toward the beginning of March she became so much worse that all her relatives and friends were very seriously concerned about her. She expired toward 5 o'clock in the afternoon of March 18. About 3 o'clock on that day Berthelot, who had an office in the Palais de l'Institut as perpetual secretary of the Academy of Sciences, asked his colleague, M. Dartoux, before the session of the Academy, to look over his mail, for his wife's condition worried him. The members of the Institut saw him cross the court with his usual short, hurried step and enter the scientific establishment. He went at once to his apartment to take his place beside his wife, who was then quietly passing away.

When all was over and while they were beginning to prepare the body for burial, M. Berthelot, completely broken down, left the chamber and went in the next room to lie on the couch where he was accustomed during the day to snatch a few moments' rest. When he went out he was heard to say, with his hand on his chest: "Oh, something here is suffocating me! * * *"

Very shortly afterwards they went into the room to see how he was. He lay streached on the couch breathing hard, and everything that was done for him proved useless. He succumbed almost immediately, following a severe checking of the heart action caused by his emotions, and it was in vain that the physicians, called back with all haste, tried to restore him. The great chemist was dead; he could not bear up under the loss of his distinguished wife, with whom he had lived for so many years in such a perfect union.

Then he added: "I was talking last night of the past, with Madame Berthelot, and we arrived at the conclusion that I had not lived a year without having a struggle to keep up." Sincerity always ends in triumph. On November 24, 1901, in that memorable meeting on the fiftieth anniversary of the professor's scientific career, the scholars of the whole world came to pay their respects in recognition and admiration of Berthelot.

After having listened to several of the two hundred addresses coming from all corners of the civilized world, Berthelot arose and in the midst of the general emotion, in a clear and distinct voice, made a memorable speech, of which I shall try here to recall the beginning:

I am profoundly touched and completely overcome by the honors that you bestow upon me at this moment. These honors, I know, are not due alone to your personal regard for me; I should attribute them also to my age, to my long labors, and to such services as I have been able to render to our country and our fellow-men.

To my age first of all. Your sympathy makes it shine like the last burst of light from a lamp on the point of being extinguished in eternal night! The respect that humanity pays to the aged is the expression of the binding force that unites the present generations with those that have preceded us, and with those that are to follow.

What we are is due but in small measure to our own labor and to our personal individuality, for we owe it almost entirely to our ancestors—ancestors by blood and ancestors of our character. If any of us add anything to the common good in the realm of science, of art, or of morality, it is because a long line of generations has lived, toiled, thought, and suffered before us. It is the patient efforts of our predecessors that has created this science that you honor to-day.

Each one of us, whatever has been his individual initiative, should likewise attribute a considerable part of his success to contemporary scholars competing with him in the great common task.

In fact, for the brilliant discoveries of the past century, for these discoveries, let us proclaim it boldly, no one person has at all the right to claim exclusive merit. Science is essentially a collective work, pursued during the course of time by the efforts of a multitude of workers of every age and of every nation, succeeding themselves and associating by virtue of a tacit understanding for the search for pure truth and for the applications of that truth to the continuous betterment of the condition of all mankind.

CAROLUS LINNÆUS, 1707-1778.

LINNÆAN MEMORIAL ADDRESS.[a]

By EDWARD L. GREENE.

INTRODUCTORY.

THE personality of Linnæus and his luminous career as a scientific man make a topic much too large to be presented even in mere outline within the limits of an hour. If this were an assemblage of botanists exclusively, still would the time be too short for the worthy consideration, not only of Linnæus as a botanist in general, but of his services to any one only of the several departments of the science which it is his glory greatly to have advanced. But then, a botanist, a very great botanist, he was also much more than that. I have a fancy—it may be more and deeper than a fancy—that a great man in whatsoever profession, a man of power in any branch of science, is greater than the science to which he devotes himself; that he himself personally is of more moment, and ought to be of deeper interest than his science; yes, than all the sciences that are or ever shall be.

If we could in thought divest Linnæus of his systematic botany and zoology, we should still find ourselves in the presence of a man of the highest educational accomplishments and general culture, clear-headed and original as a thinker, a philosopher, religionist, ethnologist, evolutionist, traveler, geographer, and a most able and polished man of letters. These are many different aspects of a great character, the presentation of which, one by one in a discourse, might interestedly engage the attention of others besides nature students.

Confronted by so very much that may be said, and which it might seem ought to be said on this day dedicated to Linnæus, and, checked by the consideration that only a few selections from out the whole mass may at this hour be taken, where shall one begin? Whither shall one proceed? What thrilling passages in a career

[a] Delivered at a joint meeting of the Washington Academy of Sciences, the Biological Society of Washington, and the Botanical Society of Washington, held at Hubbard Memorial Hall, on the occasion of the two hundredth anniversary of the birth of Carl von Linné (Carolus Linnæus), May 23, 1907. Reprinted by permission, from the Proceedings of the Washington Academy of Sciences, July, 1907.

so almost marvelous shall be left unnoted for want of time, and of what few of them shall the rehearsal be attempted? Or, reducing these questions down to two: Shall the *man* be presented with citation of his struggles with adverse circumstance, and of the almost incredible patience, industry, zeal, and resolution with which he conquered and rose to high renown? Or shall one consider rather the *work* of the great master of botanical theory and taxonomic abstraction? There will not now be time for both; not even though attempted in mere outline. My own inclinations favor choice of the latter, especially for to-day; yet circumstances indicate that such a choice would here be also inopportune. Our Washington botanists at this season of the year are mostly far afield, in the service of the Government. Only a fair delegation of my colleagues in this science is here present; and this enlightened audience as a body I am persuaded would much rather hear something more about the *man* of whom all the world of education and of culture has heard more or less. Even on my own part I have already expressed the view that the *man* should first be known, that we may the better comprehend his deeds.

LINEAGE AND CHILDHOOD OF LINNÆUS.

When Linnæus, on the 23d of May, two hundred years ago, was born, I think it had long been predetermined that he should be a botanist, and one of high distinction. When I say predetermined, I do not use the word in any sense of theological predestination or of astrological forecast. I have but the recognized principles of natural heredity in mind. And, unless I err, there was more inherited by Linnæus than his biographers seem to have guessed. They all repeat it that the father, the Rev. Nils Linnæus, a Swedish country clergyman, was fond of plants, and had a choice garden wherein he took his daily pastime, and that in this garden his first-born child developed those predilections which at length became the despair of the father, yet led the son eventually far up the heights of fame. All this is authentic, and well told by the several biographers; but there is more in that history which to me seems well worth telling, and will give light upon the derivation of Linnæus's genius as a botanist and upon his accomplishments as a man of learning and of letters. Let us go back to the second generation of his ancestry and glance at men, women, and social conditions.

The grandfather of Linnæus, on his father's side, was a Swedish peasant, by name Ingemar Bengtson. His wife had two brothers who became university graduates, were afterwards clergymen of some distinction, and men of reputation in the world of learning. These uncles of our Linnæus interest us because of their having fig-

ured somewhat conspicuously as stars of destiny in relation to him long before his birth. They even had somewhat to do with the originating of the family name Linnæus. But for their influence in this direction it is probable that their grandnephew, then unborn, if he had distinguished himself as he did, would have been known in history and to fame not as Carolus Linnæus, but as Karl Nilsson. That both these granduncles of Linnæus were Greek scholars seems attested by the fact that, in assuming a new family name, after the mediæval usage of those who arose from the humble estate of peasantry to the aristocracy of learning, they choose the Greek name Tiliander. They were Karl and Sven Tiliander. In their boyhood they had been known simply as Karl and Sven Svenson, and if they had remained uneducated, and in the same lowly and simple estate in which they were born, they would have been known by those names to the end of their lives. Karl Tiliander rose to wealth and station, adopted a coat of arms, in a word, was an aristocrat, but died childless. His grandnephew, however, born ten years after his death, was named in his honor. In fact, Karl Tiliander and Karl Linnæus are, in meaning, the same name precisely. Now the other great uncle, Sven Tiliander, was a minister, had a family of minister's sons to educate, and was generous enough to receive as one of his own sons his sister's son Nils, to be educated with them. This peasant boy, Nils Ingemarsson, remember, is the predestined father of our Linnæus. But this boy's school scene, lying away back almost upon the edge of mediæval times, and afar in the north of Europe, well toward the country of the midnight sun, is a pleasant scene, before which we must pause a moment. It is in midst of a time when great people may lead simple lives, and when a family group of boys, destined if possible to the intellectual life—and at least to one of the learned professions, are not at first to be sent away from home. They live under the parental roof, and their Latin tutor lives there with them. That is the language in which, later at college and at university, lectures on all subjects will be given; it will be the language in which most of the books there used are printed, the language of recitation and of student debate.

So these small boys at home begin Latin. They also so begin it as if they were to become interested in it, and really to learn the language, and not to end with a mere smattering of it. They are to speak it, as well as read and write it. Therefore it becomes at once, in as far as possible, the medium of spoken intercourse between tutor and pupils, the father of the family himself incidentally aiding the tutor by addressing the youngsters at mealtime or recreation in Latin, and requiring them to answer in that, and not in the mother tongue. It was a serious business; the entrance to college, the matriculation at any university, the rising to any learned profession even, are dependent upon the boys having made good progress in the

acquisition of this, at that time the universal language of the educated. The Swede or Finlander even, if a college man, might visit every country of Europe, and converse with the men of the colleges and universities everywhere, without learning one of the modern languages. Linnæus even, two generations this side of the epoch of his great uncles, the Tilianders, did this. Now, among this aristocratic caste of the learned, in mediæval times and later, it was almost the universal custom with men of lowly origin to drop the ancestral family name and assume a Latin one. It was a fashion of the time; and, as I have said, the time lasted through many centuries. When Latin was the language of a certain social caste and the language of almost all authorship, the canons of good taste seemed to require that the author of a book in Latin should put his name in Latin on the title-page, and not in some barbaric Teutonian or Russian or Scandinavian or English form, to which, as to a plebeian inheritance, he might chance to have been born. Such is the origin of the general circumstance, familiar to all botanists, that nearly all the thousands of volumes of botanical literature that antedate the beginning of the nineteenth century are by authors whose names are plainly Latin names. The same is true of the earlier literature of all our sciences. It was all in Latin, and the authors' names are Latin names.

The greatest name in astronomy, but for the man's Latinization of it on the title-page of his immortal book, would have come down to posterity as Kupernik. But all astronomers and all other people besides should be grateful that, the book being in Latin, he wrote himself not Kupernik but Copernicus. The most illustrious of old-time Chinese sages was and is known to his countrymen as Kung-fu-tsee; but the Latin scholars who, some centuries ago, first brought him to the notice of the western world wisely and tastefully Latinized Kung-fu-tsee to Confucius. A single generation earlier than Linnæus there flourished in Germany one of the greatest botanical celebrities which that country has produced. His splendid folios are now so rare that only the choicest botanical libraries of to-day are able to catalogue a set of them, and they were very helpful to the young Linnæus. This famous German, as a boy, and before his college days rejoiced in the plain everyday Teutonian name of August Bachman. Afterwards, as professor of botany at Leipzig and the author of immortal books of botany in Latin, he assumed the most perfect counterfeit of an ancient classic Latin personal name which I can recall. This August Bachman is known in history and to fame as Augustus Quirinus Rivinus. The name Rivinus was arrived at in the simplest kind of a way, for it is nothing but Bachman—the man who dwells by a rivulet or brook—translated into Latin. Now just as Rivinus—in German Bachman—recalls a stream bank where the

Bachman family lived, so those forebears of Linnæus who, on rising to the rank of gentry, took the Greco-Latin name Tiliander, chose that improved appellation in allusion to an object in the landscape near their home. That object was a remarkably large and ancient linden tree, a tree of special note all over that part of the country. Tiliander, Lind-tree-man, or, more in brief, Linnman. In Swedish it would be Lindman. So these two learned brothers, who became the head of the Swedish family of the Tilianders, chose a botanical name, incidentally presaging the botanical halo that was to glorify a future scion of their stock under the same name somewhat altered. Now if the name Tiliander was prophetic incidentally, it had not been chosen accidentally.

The Rev. Sven Tiliander, uncle and foster father of the father of Linnæus, was a devoted lover of trees and plants. It was that passion for botany which determined his taking the new and classic-sounding family name from the great linden tree. At the time of his taking his nephew Nils Ingemarsson into his family to make of him if possible a scholar and a Lutheran priest, he had extensive orchards and gardens to the care and improvement of which he was enthusiastically devoted. This enthusiasm for such things became contagious in the case of his nephew Nils, insomuch that the boy found delight in going with his uncle and helping him in orchard and garden. Twenty years or so afterwards, when this nephew, now a learned graduate and assistant minister of a parish, as the Rev. Nils Linnæus—no longer Nils Ingemarsson—he was so deeply imbued with the love of the beautiful things of the plant world that he began the establishment of orchard and gardens on the parish farm when his residence was established. A word here as to his new name Linnæus, which had now displaced that peasant's name, Ingemarsson, to which he had been born. Reared and educated along with his first cousins, the Tiliander boys, it may be assumed the whole family may have thought it better that, as scholar and gentleman, he should take some other name than Tiliander. At all events, and quite as if in grateful love of his uncle and cousins, he took a name precisely the equivalent of theirs—the name of Linnæus. It is not quite as elegant in its construction as Tiliander, but its meaning is just the same. It is another way of turning Lindman into Latin. And so Nils Ingemarsson, by changing his name to Linnæus, paid high compliment to that uncle and benefactor, Sven Tiliander, to whom he owed so very much, commemorated again that ornament of the northern landscape, the great linden tree, and supplied to all scientific posterity the illustrious and immortal name Linnæus. In view of this, that the most signal and lasting service that the greatest Linnæus rendered botany was the reform he wrought in the Latin nomenclature of plants, the derivation of his own name, its botanical

origin and character, can not fail to be of interest to all who, on this his two hundredth natal day, unite in celebrating his imperishable fame.

The Rev. Nils Linnæus was no sooner married and settled in the charge of a parish than he began the creation of an orchard and garden, following the inspiration he had received in boyhood while under the benign influence of his uncle, the Rev. Sven Tiliander. When Nils Linnæus's garden had been four or five years established, the proprietor began to lead within its precincts his first-born child, a small white-haired boy, active and intelligent beyond the average for his years. Flowers, beyond all things else, were this small child's delight. Even at the age of four years he knew the names of all the familiar kinds. On a May-day picnic excursion that the pastor gave the children of the parish, to a wild and beautiful spot some few miles away, this botanical nomenclator, that he was to be, nearly monopolized the pastor's time with questions of plant names. Many kinds, to him until now unknown, and therefore nameless, he must have names for. Some of them were forgotten within an hour, and were brought again. The father's patience gave way a little, and the threat was made that unless Master Karl Linnæus was more careful to remember them he would get no more plant names at all. If the Rev. Nils Linnæus had thought it time to begin to check his child's extraordinary zeal for plant knowledge, this was the wrong way to go about it. That threat, though a mild one, would be sure to have the opposite effect. If the infant had inherited the father's temperament, the matter would have been unimportant. I may rather say that, if the child Linnæus had been of the father's temperament, this restless activity and burning zeal, whether for plants or for anything else under the sun, would not have been there, and that small white-haired Scandinavian child's birthday would not have been celebrated on two or three continents after two hundred years.

If a paradox like this may be ventured, one may say that the fatherhood of a great man must, in many an instance, be credited to the mother. The man of power and influence may have for his male parent one of quiet, retiring manner, unaggressive, unambitious, and even slow, if the mother be very decidedly of the opposite temperament, active, energetic, ambitious, ardent, and also young, strong, and in perfect health. Just these conditions prevailed at the nativity of Linnæus. The strong character in that household was the mother, Christina Broderson Linnæus. It is safe to infer from her antecedents that she was a woman of refinement and perhaps unusual mentality. She may almost be said to have had none but cultured men among her ancestry for three generations back. We have already seen that her husband was her father's successor in the Stenbrohult pastorate. Her father had not only been pastor there all his official life; he had

been born there, as the son of the pastor whom he in turn succeeded; so that her father and her grandfather had been pastors of that parish all their lives—so to speak—while the priest who preceded her paternal grandfather in that same church had been her great-grandfather on her mother's side. Realizing now that, when in the nineteenth year of her own age Christina Linnæus's first-born arrived at the parsonage where both she and her father before her had been born, where a grandfather of hers and even a great-grandfather had held life-long pastorates, we pardon the ambition of the young mother who set her whole heart and soul upon the plan of having this her first-born trained and fitted to inherit that pastorate already historically so remarkable, of which history she could not but be proud.

SCHOOL, COLLEGE, AND UNIVERSITY YEARS.

The mental training of the child Linnæus was, of course, begun at home. At 7 years of age he was well enough advanced to have a tutor. At 10 he was sent away to a Latin school and theological preparatory at Wexiö, not many miles from home. After eight years there, the progress made in studies looking to the office of a Lutheran ecclesiastic seems not to have been satisfactory; and now the Rev. Nils Linnæus came journeying to Wexiö. The instructors whose duty it had been to train the boy in Hebrew and biblical learning had failed to interest him, and they said to the father that they could not, on their consciences, advise him to continue the youth at school. In their view it would be better at once to apprentice him to the learning of some handicraft, that of carpenter or tailor, for example. Doubtless this counsel would have been followed but that Pastor Linnæus had another errand at Wexiö that must be attended to before the disheartened return to Stenbrohult, whether, as it now seemed, he would have to convey his son, now 18 years old, as withdrawn from college because of his having no taste for learning; that is, theological.

Pastor Linnæus's other errand was that of placing himself under the direction of an eminent physician of Wexiö as to an ailment of his. The physician was Doctor Rothman, who was also a lecturer on medicine at the college; and this man, as it happened, both knew and was much interested in the youthful member of the Linnæus family. When the father confidingly mentioned his deep grief over his son's failure at school, Doctor Rothman was able to cheer him with a very different account of his boy's proficiency. He was so confident that out of this bright youth a great physician might be made that he proposed to receive him, with the father's consent, into his own house for a year and give him special instruction, free of all charge; and this was done.

Now, while making himself the despair of his tutors in Hebrew and theology, what had the young Linnæus been accomplishing all these years? The idler which these thought him he had not been. In mathematics and physics he was quite distinguished; moreover, his student comrades called him always the little botanist, thus by chance conveying the information that, as a youth of 18 years, Linnæus was small of stature, and as much as possible given to botanizing. He has told us himself that, during all his years at Wexiö, the red-letter days were those of his occasional walks across the country 30 miles to the home at Stenbrohult, which gave opportunity to study the wild plants of the waysides. He had also acquired certain books on botany—Swedish local floras—in the study of which he had busied himself day and night until he almost knew them by heart, as he assures us. The titles of at least three of those books, and especially their authors' names, must needs be given on a Linnæan bicentenary that is celebrated in America. The fitness of this mention you shall see. One of the books was Rudbeck's Hortus Upsaliensis (1658); another was Tillandsius's Flora Abœnsis (1673); the third Bromelius's Chloris Gothica (1694). It was to the grateful memory of these Scandinavian botanists, Rudbeckius, Tillandsius, and Bromelius, all of them dead before Linnæeus was born, that he, in the days of his own fame, consecrated those fine American genera, *Rudbeckia*, *Tillandsia*, and *Bromelia*. These men, by their books, had been his teachers of botany while he dwelt at Wexiö between the eleventh year of his age and the nineteenth. It is true that the works of these men were not of the nature of what would now be called scientific botany; that is, the plants discussed were not arranged according to any notion of their affinities. The order followed was either that of the alphabetic order of their names, as in a common dictionary, or else, if they were grouped at all, the grouping was according to their medicinal properties or other economic uses. All these books, so much beloved and revered by the youthful Linnæus, had been published before Tournefort, who, practically, and at least for the time immediately antecedent to Linnæus, was the father of natural system in botany.

It was as an inmate of Doctor Rothman's household, and while preparing under his direction to enter some university as a candidate for the doctorate in medicine, that a new day dawned upon Linnæus's horizon in respect to his botanical recreations and pursuits. The botanical system of Tournefort had now been before the public for some thirty years. His work was the most complete and signal success that ever had been, and I may almost say, that ever yet has been, in the field of botanical authorship, because it seems to have captivated the whole botanical world without arousing a jealous enemy or eliciting a line of adverse criticism for twenty years, save only a mild protest from the gentle John Ray in England, who, clearly superior to

Tournefort as a botanist, never measured half the latter's success as an immediate and popular influence. Viewed without bias or prejudice, and in the perspective of two centuries, Tournefort's Institutes becomes the most conspicuous landmark in the whole history of botany. By no other one author's help did the science make a stride in advance equal to that made under Tournefort's influence between the years 1694 and 1730. It is important that these things be taken note of here. On the day when Linnæus was born two hundred years ago, Tournefort's dazzling star was high on the botanical horizon. It was at its meridian when, at 18 years of age, Linnæus fell under the benign influence of Doctor Rothman at Wexiö. This man made no pretensions to botany, beyond what any first-class practicing physician of that period had to know; but he had full knowledge of the great fame of the Parisian, Tournefort, and had in his library the German Professor Valentini's [a] abridgment of Tournefort's Elements. Doctor Rothman had evidently studied Tournefort and been fascinated with his system. Linnæus, the youth, away in the distant north, the pupil of none but theologians, had not so much as heard of Tournefort. Rothman told him frankly that all his recreations with plants were little better than wasted time unless he should begin to recognize them as interrelated by characters of their flowers, as Tournefort had taught.

From the day when Doctor Rothman placed in his hands Valentini's key to the twenty-two Tournefortian classes of plants, the young Linnæus bent his energies in botany to ascertaining by their organographic marks to what one of the classes of Tournefort each plant that he found belonged. It was a day that completely and most happily revolutionized this brilliant youth's conception of the plant world, as well as his method of investigating it. It was, in fact, the day when Linnæus, according to his own testimony about it, first began to be a botanist; and thenceforward the illustrious Parisian had never a more zealous disciple, until after some years the ardent disciple began, and in some respects deservingly, to supersede the master. It is hardly to the praise of Linnæus that in after life, when at the height of his own resplendent fame he was dedicating a genus of plants to each of his chief benefactors of earlier days, he forgot good Doctor Rothman. This man had been the first, and perhaps the most important of them all, even from the view-point of botanical training. It was certainly he who, as far as one can see, saved the boy Linnæus from oblivion when his own father had resolved to apprentice him to a cabinetmaker or a tailor. It was he who, having assumed, as it were, sponsorship for Linnæus as candidate for a career in science, placed in his hands the first book of real botany that the

[a] Valentini (Michael Bernhard), professor in Giessen. Tournefortius Contractus, Frankfurt am Main. 1715, folio, pp. 48, 4 tab.

youth had ever seen, and taught him how to begin to be a botanist; introduced him to the illustrious Tournefort, who at once became the lode star of Linnæus's own genius for years to come. Yet to the end of Linnæus's days there was no genus *Rothmania*. Professor Thunberg, once a pupil of Linnæus at Upsala, and long afterwards a successor of his in the chair of botany there, made tardy reparation to the neglected memory of Doctor Rothman after both benefactor and beneficiary were dead.

After one year under Doctor Rothman's patronage and instruction, it was thought advisable that Linnæus should enter the university at Lund. In connection with the transfer from Wexiö to Lund there was an illustration of how, in the extremities of their need, fortune favors at every turn the men of genius and of high destiny. It was requisite that the candidate should carry a formal letter of transfer from the head master of Wexiö Academy to the rector of the University at Lund. The head of the Wexiö school, a professor of divinity, must have been the selfsame who, one year before, had counseled Nils Linnæus to abandon all hope of Karl's ever becoming a clergyman, to take him home, and apprentice him to the learning of some useful handicraft. To this man young Linnæus had to make application for the necessary credentials. As a matter of routine duty, the letter was indited promptly, and handed to the applicant. It was brief, and rhetorical; and, whether by chance, or of deliberate purpose, the figure of speech employed was botanical. "Boys at school," he writes, "may be likened to young trees in orchard nurseries, where it will sometimes happen that here and there among the sapling trees are such as make little growth, or even appear like wild seedlings, giving no promise, but which, when afterwards transplanted to the orchard, make a start, branch out freely, and at last yield satisfactory fruit."

On reaching Lund, Linnæus first of all paid his respects to Prof. Gabriel Hoek, who some years before had been an esteemed tutor of his in the earlier days at Wexiö. This gentleman was so much pleased at seeing young Linnæus there as a postulant for admission to the university that he at once, and in complete ignorance of that humiliating letter, proposed to himself the pleasure of introducing in person his former pupil to the Rector Magnificus and also to the dean, and asking that he be registered as his own former pupil. This done, good Prof. Gabriel Hoek, like a veritable angel guardian and helper, and knowing the indigence of Linnæus, went further and procured for him free lodgings under the hospitable roof of one Dr. Kilian Stobæus.

Doctor Stobæus, at the time only a practicing physician to the nobility and gentry at Lund and the regions round about—though afterwards one of the head professors at the university—at first saw

in young Linnæus nothing but an indigent student with the profession of medicine in view, his only possessions seeming to be a few books of medicine. But the student, on the other hand, found the Stobæus domicile a wonderful and fascinating place. There was a library, evidently precious, because it was kept locked. There were, however, open to any one's inspection a number of cabinets of natural history, collections of minerals, shells, birds, and—what Linnæus, though he was now 20 years old, had never before seen—an herbarium, a collection of pressed and dried botanical specimens. On this suggestion Linnæus at once began making an herbarium of his own, its contents being the plants of Lund and its vicinity. But what he wished for beyond anything else was access to the library, though he did not dare ask for the privilege. There he would be sure to find the works of Tournefort, original and unabridged, and even older and rarer standards of the best botany. The privilege came at last, and in a remarkable manner, by a chain of circumstances that demonstrates the young Linnæus's irrepressible zeal and most unexampled industry in acquiring knowledge of botany.

Doctor Stobæus, the owner of the first museum of natural history that Linnæus had beheld was, by Linnæus's account of him, not only of great learning and of surpassing skill in the healing art, but also himself a feeble sickly man, having but one eye, being also crippled in one foot, and a gloomy hypochondriac. A student or two in his household was a necessity. Much of his medical practice was by correspondence, and on some of the professional visits the student must be sent. At the time of Linnæus's coming, a medical student from Germany had long been Doctor Stobæus's main dependence for help; was thoroughly trusted, and his right-hand man. This older student the magnetic young Linnæus in an innocent way, and half unconsciously, appears to have at first captivated and then bribed into helping him in respect to that which he now most desired.

An old and honored inmate of the doctor's household was his mother. She was a nervous, fretful old lady, much troubled with sleeplessness. A window of young Linnæus's room was visible from where she tried to sleep, and she observed that, after this newcomer had been in the house some weeks, a light seemed to be left burning in his room, if not all night, at least until well toward morning, when presumably it had burnt itself out. She reported the case to her son, and insistently, as a thing that ought by all means to be stopped. The whole house was in danger of destruction by fire. Doctor Stobæus had knowledge of students and their ways. In his own mind he doubted that this was a case of sleeping with the candles burning. He entertained a suspicion that the two companion youths would be found there, recreating themselves with cards in the small hours of

the night. At 2 o'clock next morning, the room of young Linnæus being illuminated, the doctor quietly made his way to the door, opened it and went in. The young man was found alone, at his study table, which was covered with open books. A step nearer the table disclosed the interesting and not readily accountable fact that all were books of botany, and out of Stobæus's own library that was always kept securely locked. To the question how he obtained those books from the locked library Linnæus answered in brief, and very frankly, that the other student had desired of him a course of instruction in physics; that he had begun the course, and was continuing it, upon the stipulated condition that he, who had free access to the library, should nightly bring him books of botany, which he himself would study late at night, so that they might be returned to the library shelves in the early morning before the household should be astir. Doctor Stobæus, suppressing the pleasure and approbation that were mingled with his amazement, said, "Go to bed, and hereafter sleep while other people are asleep." The next morning he sent for Linnæus to come to his study, asked him to rehearse again the story of how he obtained those books, then gave him a duplicate key to the library, together with permission to use it as freely as if it were his own. Moreover, as he had hitherto nothing but his lodging with Stobæus, he was now invited to take his meals at his table; was often sent to visit patients, and in every way treated with affectionate regard.

When nearing the end of his year at Lund, Linnæus fell dangerously ill. At the beginning of a slow convalescence they sent him to the parental home, the parsonage at Stenbrohult. Here his admiring first patron, Doctor Rothman, of Wexiö, visited him. He was now ambitious that his former pupil, instead of returning to Lund, should enter the great university at Upsala, where men of renown occupied professional chairs, Roberg in medicine and Rudbeck the younger in botany. The parents, in view of the quite marvelous successes of their boy during the two years that they had left him without financial aid, seem to have relented, and partly forgiven his having disappointed their wishes as to a vocation, and he was given some money with which to procure conveyance to Upsala and make the beginnings of a career at that celebrated seat of learning; this, however, with the stern assurance that this was all they would be able to do; that no remittances from home would be forthcoming. Before the first year at Upsala was completed Linnæus was penniless and almost barefooted, being obliged to line his shoes with birch bark and pasteboard, and his clothing was worse than threadbare. He was now in the twenty-third year of his age, and in his distress he still consoled himself with studies botanical. In the midst of the botanic garden at Upsala he sat, one autumn day, drawing up descriptions of some rare

plants that were in bloom. An ecclesiastic of distinguished bearing, in passing through the garden, paused before him, asked him what he was describing, if he knew plants, was a student of botany, from what part of the country he had come, and how long he had been at the university, tested his knowledge of botany by asking him the names of all the plants that were in sight. This ecclesiastic was no less noted a personage than Olaus Celsius, a man then some 60 years of age, eminent as a theologian, an orientalist, and more than an amateur in the natural sciences; even now beginning to be a botanist; for some two years before the date of his chance meeting with the student Linnæus, he had been assigned by a council of Lutheran clergymen the task of writing a treatise on the plants mentioned in the Bible. His classic Hierobotanon was the result of his attempt to fulfill that commission; and, by the way, none will ever know how largely he may have been indebted to the young student Linnæus in the preparation of that work. The examination that he had given the youth, there in the botanic garden, had filled him with wondering admiration. Celsius saw that he needed him; saw also in his worn clothing and almost bare feet the evidence of a worthy student's grinding poverty. Within a few days Linnæus was comfortably housed with Professor Celsius, having been commanded to bring with him that herbarium of 600 Swedish plants which he said had accumulated with the last three years.

Celsius was to write a botany of Palestine by and by, and was now devoting as much time as he might to the botany that was at hand, that of his own country; and he had augmented his great scholar's library by the acquisition of all the standard and many rare books of botany. Linnæus was again in the enjoyment of great good fortune. Yet all this was not for long. Celsius's very zeal and benevolence on his behalf brought the young man into trouble. By his great influence he procured for Linnæus an examination, which was followed by a license to lecture publicly in the botanic garden. The candidate had not been three years in residence, and Professor Roberg expressed it as his opinion that the precedent was a dangerous one to have established. The lectures were begun, and Linnæus had a throng of students of the best class, among them sons of some of the university professors, and he was now able to clothe himself comfortably. This all happened at a time when a promising instructor, Nils Rosén, had lately gone abroad on a two years' leave to obtain the doctorate in medicine. A less competent young man had been delegated to take Rosén's work during his absence. Linnæus, by his superior learning and personal magnetism, appears quite innocently to have drawn away his students. There would be trouble in store for Linnæus whensoever Rosén should return. It is a sad truth that, in science as elsewhere in this poor, foolish world the mediocre man in

higher position must hate and if possible persecute the superior man in lower station, and that for his very superiority, if for nothing else. Rosén, on his return from abroad, with the doctor's degree won, besought of old Professor Rudbeck permission to teach botany himself, hoping thereby to draw from docent Linnæus all his students. Rudbeck declined to consider such a proposition, stating frankly that Doctor Rosén was hardly very well prepared to instruct in botany. Rosén's next move was successful. He procured the passage of an official regulation to the effect that no undergraduate should be permitted to lecture publicly, to the prejudice of a regularly appointed instructor. Such an instructor there was, in the person of the young man who had been appointed to teach in Rosén's place while he was absent. Thus was Linnæus deprived of the means of living any longer at Upsala.

JOURNEY TO LAPLAND.

Inasmuch as his lecturing in the botanic garden had been under Rudbeck's jurisdiction, and the latter had become much attached to the young man, he had taken him into his own household. Rudbeck himself had been the earliest botanical explorer of Lapland, and, by frequent rehearsal of the wonders he had seen in that wild hyperborean realm, he had enkindled in the young Linnæus a keen desire to go there. The Swedish Government had long thought its own territorial possessions there to be worth investigating from scientific and economic points of view.

It was now soon arranged that Linnæus, under the auspices of the Academy of Sciences at Upsala, should make an expedition to Lapland for purposes of scientific exploration. He set forth from Upsala on the 13th of May, 1732, returning late in autumn. It had been a journey of some 2,500 miles, made alone, for the most part, and almost everywhere on foot; but this was one of the most fruitful seasons of his whole life, though he was now but 25 years of age. His Flora Lapponica, together with the narrative of the journey, are among the most instructive and fascinating reports of a scientific expedition ever written. In the day when they were new they were unequaled in the literature of scientific travel, and the Flora Lapponica would have secured a deathless fame to any botanist, even if he had written nothing else.

JOURNEY TO GERMANY AND HOLLAND.

After the return from Lapland, the next two years were passed in teaching publicly and privately, at one place and another in Sweden, mostly at Fahlun; but also at every spare hour of time working industriously at the manuscripts of several books—the Flora Lapponica and others—which he was all the while hoping

soon to be able to give to the public. At Fahlun he won the esteem and friendship of the Rev. Johan Browallius, at that time private chaplain to a certain nobleman, subsequently a professor at the University of Abo, and Lutheran bishop of that diocese. This man urged Linnæus to circumvent his powerful antagonist at Upsala by going abroad, and taking his degree in medicine at some foreign university. Following this counsel, Linnæus, in the beginning of the year 1735, sailed for Germany and the Netherlands, taking with him a finished medical thesis for presentation at some school of medicine and also the manuscripts of several books of botany. Before the end of June he had passed the examinations, successfully defended his thesis, and obtained the degree of doctor of medicine; this at Hardewyk in Holland.

The primary object of his trip abroad having been attained, there were reasons why he might have been expected to take advantage of the first opportunity that should present itself for his return to Sweden. Before leaving his native land Linnæus had acquired what is said to be easily gained by even a poor young man when he happens to be of good presence, polite accomplishments, and some personal magnetism; he had provided himself with a rich and elderly prospective father-in-law. Said prospective father-in-law had returned the compliment by providing Linnæus with some traveling funds and the needful university fees. Before bidding the prospective son-in-law farewell, Doctor Moræus, as if endowed with some of that wisdom that men say comes with years, and as if doubting that the prospective bride would surely speed the young man's early return, enjoined it upon him that he must come back and begin the practice of medicine, whensoever he should have gained the doctorate.

But that which had long been uppermost in Linnæus's mind had been, not medicine, but systematic botany. In the direction of the latter all his ambition led him. The manuscripts of what he hoped would be immortal books of botany—and they became such—he had brought with him. No one in Sweden would have published them. In Germany, in Holland, and in France there were many and splendid botanical establishments, and several learned botanical professors of world-wide fame. His books if published must have the approval of these in order to insure for them success. He must see these men, ingratiate himself with them personally, show them his manuscripts, discuss with them the merits of his system, for it was new, and in its leading characteristics altogether revolutionary. His money was now almost all gone, but what of that? He had often been in such straits before, but some provision had always hitherto been made for him.

Leyden was the seat of what, at the time, was the most celebrated university in Holland, and, for botanical gardens and botanical celeb-

rities who had taught there, was hardly second to Paris itself with its traditions of Tournefort and his successor, Vaillant. In Prof. Paul Hermann's time, little more than a generation anterior to Linnæus, the Leyden Garden had been confessedly the finest and richest in the world. After Paul Hermann, Dr. Hermann Boerhaave had presided there. He had retired from the professorship three years before Linnæus's arrival in Holland, and was now at once the most famous physician in Europe and without a rival as an authority upon systematic botany. He was living in age and retirement not far from Leyden, and there was not another man upon the face of the earth whom Linnæus so much wished to see. He could not endure the thought of returning to Sweden without having visited this great Mecca of botanists, Leyden. Once there, he found friends in learned botanists nearer his own age, who had not yet published books, and of whom he had not heard, among these, Adrian van Royen, professor at the university in succession to the illustrious Boerhaave, also Doctor Gronovius, a well-versed and ardent botanist. Others at Leyden who became Linnæus's cordial and helpful friends we must not stop to name. Both van Royen and Gronovius became enthusiastic over the young man and his manuscripts. Gronovius was so charmed with his Systema Naturæ that he proposed, with Linnæus's permission, to have it published at once, and the printing of it was begun. It came out, as a mere outline sketch of a new natural history. It was a folio tract of but fourteen pages, but it was everywhere received with the greatest applause. Meanwhile Linnæus had used every endeavor to see that great oracle of medicine and of botany, old Boerhaave, but in vain. Provided with a letter from Gronovius, he had called every day for a whole week, but to no purpose. Ambassadors and princes had found him accessible with some difficulty. Even Peter the Great, of Russia, had been obliged to wait two hours in an anteroom, to take his turn in getting a conference with this busiest and most imperious old prince of learning and master of the healing art. Linnæus now bethought himself to send a copy of the new Systema Naturæ. A letter came back, naming the day and the hour when he should be admitted to an audience. The interview was prolonged and was carried into Boerhaave's own private botanic garden, a place well stocked with almost all plants and trees that had been found to endure the climate of Leyden. One beautiful tree which Boerhaave thought—was even very certain—had never been described. Linnæus gave him the name for; also the volume and page of one of Vaillant's folios in which it was described fu[illegible] clearly. When they returned to the library the place was [illegible] as admitted. The venerable doctor advised t[illegible] in Holland, where he felt certain that his l[illegible] insure him wealth and great renown. But

now prolong his stay at Leyden, Boerhaave desired him to take a letter from himself to his friend, Professor Burmann, at Amsterdam, the port whence Linnæus had proposed to sail for Sweden. He found Burmann, then much engaged upon his Botany of Ceylon,[a] so overwhelmed with work of several kinds that courtesy seemed to require that he should make the call short. It was evident that nothing but the letter from that great scientific potentate, Boerhaave, at Leyden, had procured him admission to Burmann's presence. On withdrawing, however, he was invited to call again. At the second call he found the Amsterdam professor less preoccupied. They went into the botanic garden. At the end of this interview Burmann was overwhelmed with a sense of the unexampled skill of this young Swede in botany. He had learned so much of him in that one hour as to see that he must secure, if possible, his help in the finishing of his great book of Ceylonese botany. Linnæus was invited to take up his abode with Burmann for the period of his sojourn in Amsterdam, and he accepted the bidding. He had been there about two months when he received a call from one of the merchant princes of Amsterdam, George Cliffort. He was a gentleman of culture as well as of great wealth, and had a very noble garden and conservatories abounding in rare plants from the Indies and other remote places. But his errand with Linnæus was not botanical. He was something of an invalid, and melancholy. His regular physician was Boerhaave, at Leyden. On a late visit to him, Boerhaave had advised him that his ailments were chiefly resultant from his princely ways of living; that he could not do better than employ the services of a brilliant young Swedish physician, a specialist in dietetics, at present the guest of Professor Burmann. He advised him to take Doctor Linnæus for body physician into his own house, and place himself under his direction as to diet. This was Cliffort's motive in calling upon Linnæus. The outcome of it was an agreement between them; and the young physician botanist was soon quite luxuriously domiciled with Cliffort, and under good pay. Charmed with the Cliffortian garden and conservatories, and seeing there many a plant unknown to botanists, Linnæus counseled the preparation and publication of an illustrated folio, that might fitly be entitled the Hortus Cliffortianus, in which the rarities and novelties growing there should be brought to the knowledge of the world botanical. Of course the proposition delighted Cliffort and the work was done. That most luxurious of all Linnæus's works, the Hortus Cliffortianus, he assures us, was written in nine months. It was published in Amsterdam in 1737, when Linnæus was 30 years old. But besides this, there had already been published, since Linnæus had come to Amsterdam, the Bibliotheca

[a] Thesaurus Zeylanicus. 4to. 1737.

Botanica, and the Fundamenta Botanica, in the year 1736, and there now followed the Flora Lapponica, the Genera Plantarum, and the Critica Botanica, all in the year 1737, some of them issued at Amsterdam, others at Leyden. This represents the most wonderful beginning at botanical authorship of which there is any record. Here were seven learned and forceful books, two in folio and five in octavo, all given to the public within two years, almost a library of botany, and that a new botany, and so easy to comprehend, that almost any educated person could now acquire proficiency in botany by these books alone as a guide. The system was a new one, evidently a rival system to that of Tournefort, which had now been dominant for forty years. All the botanical world was in amazement, and the author, having now been three years abroad, and having made his personal impression upon nearly all the botanists of London and of Paris, as well as upon those of Germany and Holland, went home to Sweden, there at first to suffer the adverse consequences of fame and afterwards to enjoy its benefits.

PRACTICES MEDICINE IN STOCKHOLM.

To suffer, I say, the consequences of renown, for Linnæus had now to realize the truthfulness of what was said by the Great Master of long ago, namely, that "a prophet is not without honor, save in his own country and in his own house." At the University of Upsala now, as aforetime, there was no hope of preferment for Linnæus. His books did not as yet bring him income. He must settle down to the practice of medicine, and he chose Stockholm, the capital and chief city of the Kingdom. There he was a stranger. There was not one friend to recommend him, and, as he himself records it, no one would employ him, even by committing a sick servant to his care. His system of botany began also to be assailed in public vigorously and tellingly. Just across that arm of the sea that separates Sweden and Russia, at St. Petersburg, Professor Siegesbeck had written and distributed a book in which the Linnæan system of botany was arraigned severely, and with so much point that many people in Sweden thought that Linnæus had been philosophically and botanically annihilated. He admits that he almost believed that himself; and, as now the tide had set strongly in his favor as a medical practitioner at Stockholm, he had resolved to abandon forever the service of Flora and devote himself wholly to that of Æsculapius. The latter, said Linnæus, brings all good things, while Flora rewards me only with Siegesbecks. And the tide of Linnæus's fortune in medicine rose higher. One and another of the nobility became numbered among his patients, and at last the qu[illegible]; and no[illegible], as he said in a letter to a friend, no one who [illegible] it seemed without his help.

APPOINTED PROFESSOR AT UPSALA.

Court influence now procured him the comfortable position of physician to the admiralty. After that the death of Doctor Roberg, professor of medicine at Upsala, opened the way to Linnæus's promotion to a professorship at that university. It was that of medicine, and that of botany was, at the time, held by Linnæus's former antagonist, Rosén. The two professors, now equal in official rank, became reconciled, and, with the full consent of the authorities, exchanged professorships. Linnæus was now again a botanist. He was still a young man, only some 34 years of age, and had lived out not quite half his days. The after years, those of his fruition, did not produce as much of importance to botany as the earlier period had yielded. There came out in 1751 the Philosophia Botanica, partly of the nature of a recension and enlargement of two of his early books, the Fundamenta Botanica and the Critica Botanica. It is one of his most important and imperishable books. In 1753 appeared the largest and most comprehensive of his works—the Species Plantarum. During the remaining years of his life Linnæus was largely occupied with the preparation of new editions of almost all his works, the public demand for which was very great.

INFLUENCE OF LINNÆUS UPON BOTANY.

It is not possible to convey an idea of what Linnæus accomplished for the advancement of botany without presenting, in brief outline, a view of what had been done before him. That there was not much botany before Linnæus is a fable that gained popular credence in rural districts a half century ago. One of the earliest books which our Linnæus published was the Bibliotheca Botanica. It contains the titles of 1,000 volumes, by almost as many different botanists, most of which books he thought an indispensable part of a working botanist's equipment; and his own works, on almost every page, abound in citations of those of his predecessors. The first foundations of scientific botany had been laid by Cæsalpino, an Italian physician and university professor of botany, 124 years before Linnæus was born. He selected his granite blocks of principle so well, and laid them so securely, that the superstructure of modern systematic botany rests upon them. Every variation of botanical system that has been builded in the last 324 years has rested on the Cæsalpinian foundation, i. e., that in the fruit and seed of plants we have the key to their affinities. Not one of the great geniuses botanical in later times who have most advanced the science has questioned the validity of that principle. Not one has yet dared to predict that the Cæsalp[illegible] foundations are likely ever to be abandoned as insecure.

by differences in the structure of the corolla. The Linnæan classes were very much more easily learned than the Tournefortian. His Class I embraced all genera of plants the flowers of which have but a single stamen; Class II those which have two stamens, and so on up to Class X, when other considerations, still in part numerical, were seized upon. Any mere beginner in botany, with a plant in flower before him, could determine its class without even opening the book. If the flower exhibited five stamens the plant was sure to belong to some genus of Linnæus's Class V. If the same flower showed also two pistils, that indicated as unmistakably Order 2 of Class V. No other system of plant classification ever invented made the beginnings of botany so easy; no other ever was so immensely popular. But what is much more to the credit of the Linnæan classes and orders than the popular applause with which they once were hailed is the fact that the determination of plants under them necessitated close inspection of all, even the minutest and obscurest parts of every floral structure, trusting that in these minute, obscure, and hitherto neglected organs there would be found some of the very best indexes of affinity. This line of investigation, so important to all taxonomy, Linnæus was the very first to carry into practice and make universal. It will be difficult to bring the average botanist of to-day to a realization of how great an epoch in botany Linnæus created when he began examining the stamens of every plant, with the purpose of ascertaining into what one of his 23 proposed classes of flowering plants each generic type must fall. And though it be true that the classes and orders of Linnæus fell into disuse three-quarters of a century ago, it is true to-day that every botanist, from the mere beginner in taxonomy to the most accomplished master of it, if he have a new and unknown plant in hand for determination, makes his final appeal to stamens and pistils. These, by peculiarities of structure, will tell the plant's relationship in many an instance, both promptly and decisively. In this procedure every botanist who lives is distinctly a disciple of Linnæus; for he, putting Vaillant's principles into taxonomic practice, first inaugurated the method, and eventually brought to pass its universal recognition and its permanent establishment.

When in the year 1735, with those manuscripts of his new botanical system, Linnæus went to Germany and Holland, he had now for seven years been scrutinizing carefully and industriously the stamens of everything that had come to hand. By dint of those seven years of industrious investigation of these organs he had not only become very expert in this line, but he was the only man in the world who knew anything about the morphology of stamens. He was now, to the oldest and most experienced systematists of Europe, a perfect marvel

on account of the readiness with which he could solve for them some of their most perplexing taxonomic puzzles. I can not stop to cite more than a single instance. In one of the larger Dutch herbaria there was a rare specimen of the leaves and flowers of a certain oriental tree. The bark of this kind of tree had been known in Europe as a commercial importation for, I think, some 2,000 years. They called it cinnamon. As a generic type the tree had been named in Latin *Cinnamomum*. The professor gave Linnæus the information that these were the leaves and flowers of the cinnamon tree; but what were the natural affinities of the tree? Had it consanguinity with any other known tree? To what was it related? These were questions which not the most expert botanists could answer. The fruit of the tree was not yet known, and therefore could not be appealed to. The flowers were small and insignificant. Linnæus took one of those small dried-up flowers, subjected it to moisture, so that he could get a view of the anthers without breaking them, then, looking at these alone, was able to answer, with the most perfect assurance, that this cinnamon tree is a very near relative of the familiar sweet bay of southern Europe; a species of the genus *Laurus*. The man's frequent solving of enigmas like this, in the presence of the most learned and capable botanists of the world, brought it to pass that he was spoken of everywhere among the Germans and Flemish as the little oracle, for when he gave a decision about the affinity of any imperfectly known plant he was admitted to be correct. It was as if an oracle had spoken. These brilliant pronouncements must also have prepared the way for that great success which his publications met with and that ready adoption of his new system which followed almost everywhere, despite its character as radical and revolutionary.

If, then, Linnæus, at the time when he began publishing the fundamentals of his new system occupied a place wholly unique among botanists then living as to knowledge and understanding of floral structures of all kinds, so that the oldest and ablest among them stood in speechless admiration of his superlative attainments, there was forthwith exerted by him a most salutary influence upon the important art of plant description. The revolution which he at once brought about in the art of generic diagnosis was perhaps the most priceless of his several strong contributions to phytography. In his Genera Plantarum of the year 1737 every genus is so well characterized in words that plates and figures illustrating them are not needed. The group which Linnæus takes for a genus is even more clearly defined by his few descriptive sentences than is a genus of Tournefort, in which the defects of its description are eked out by a fine quarto plate representing the type. And the reason why

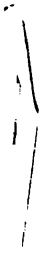
Linnæus surpassed immeasurably every author who had preceded him in the practice of generic diagnosis was that he had all their understanding and appreciation of calyx, corolla, and fruit, and added to that his mastery of stamens, stigmas, and styles, the very names of which were unknown to the generations that had preceded him, and hardly yet known to the most celebrated of his contemporaries. In the later editions of the Genera Plantarum no improvement is to be noted in his diagnoses. They were models as he gave them out at first, at least as viewed from the standpoint of Linnæus's acknowledged greater master, Cæsalpino. They are still essentially the models of generic diagnosis with all who still hold the Cæsalpinian doctrine that flower and fruit are to supply the only recognized data for the establishment of classes and genera of plants. Even George Bentham, who lived more than a century after the time of Linnæus, and was the supreme master of generic diagnosis that the nineteenth century knew, was strictly a Linnæan in this regard; so that here, as at many another important point in the most recent botany, the genius of the great Linnæus rules and directs.

Fellow-members of the Botanical Society of Washington, if this had been a meeting of our own, and not that of two other learned societies in joint session with us, I should have preferred, as I said at the beginning, to discuss some one of Linnæus's greater books, taking it as a text from which to set forth his deeds, his many benefactions to our science. To some it will doubtless appear anomalous that here not so much as the briefest abstract of his various reforms in nomenclature should be given; especially since, in the minds of so many botanists of recent decades, those reforms are thought to be the most important service that Linnæus rendered to botany. Several of the most commonly received opinions about him as nomenclator are absolutely groundless. Several principles of nomenclature now almost everywhere approved were under his severest reprehension. Inasmuch as I myself was the prime mover in the direction of what has now come to be well known abroad as the Neo-American school of nomenclature, I may be permitted to say that during more than twenty years past I have steadily and unwaveringly been of the opinion that to attempt to legislate upon nomenclature is but futility, if not folly, until every participant in every nomenclatorial conclave shall have familiarized himself with all that Linnæus said, and said with such commanding authority, upon this subject. So, then, the discussion of Linnæus as nomenclator, at least in my understanding and appreciation of him, could not alone be done within the time allotted us to-night. To omit it altogether was imperative.

The same limitations have precluded my calling attention even briefly to Linnæus as evolutionist, as ecologist, as medical botanist, or

as one who contributed much to the advancement of what is now commonly spoken of as applied botany in general.

Of the real merits of Linnæus they know little who, observing that his classes and orders are become obsolete, and that neither his idea of a genus is that of more recent botany, nor his conception of a species, conclude that his figure must by and by grow dim on the horizon of botanical history. I say, they who know little of his real merits may give place to such forebodings. But they who fully realize what he accomplished in so many different directions to the great and lasting advantage of our science will be rather disposed to wish that an equal of Linnæus might soon be born; and might think it well that the natal day of the matchless Swede should be held sacred not only once in each century, but a hundred times in every hundred years.



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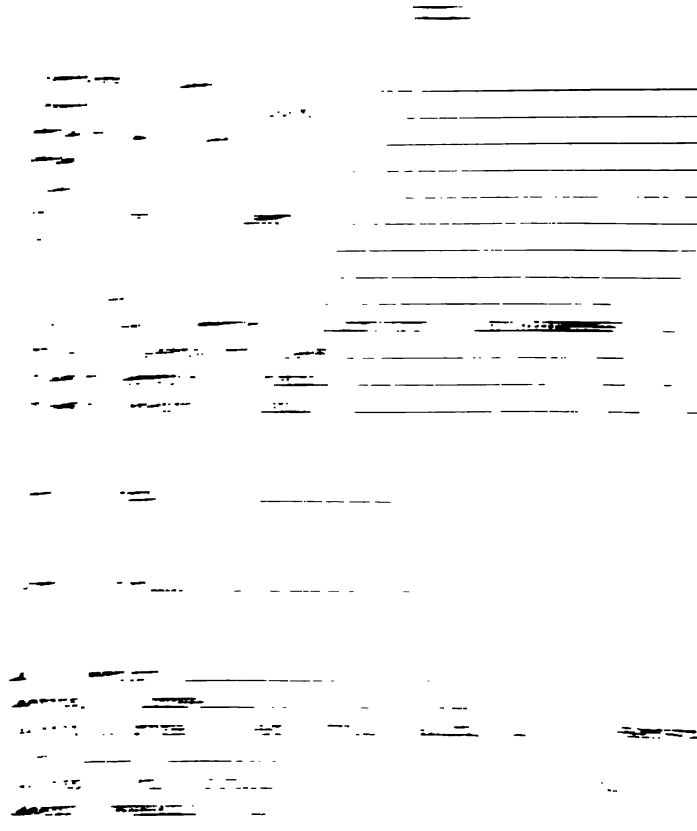
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